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CONTENTS

	Page
The climates of Alaska. (26 figs.) Edith M. Fitton	85
Gulf Stream studies: General meteorological project. (2 figs.) C. F. Brooks	103
Fog in the Ohio Valley. W. C. Devereaux	107
An unusual snowstorm in Texas. (5 figs.) Edwin J. Fosque	108
The measure of droughtiness. S. Marcovitch	113
Discussion of A. Streiff's The practical importance of climatic cycles in engineering. J. W. Shuman	114
Further studies on the electrical charges of thunderstorms. (A report of progress.) J. C. Jensen	115
NOTES, ABSTRACTS, AND REVIEWS:	
Severe duststorms over Idaho, Washington, and Oregon. O. W. Freeman	117
Snows do not govern crops. E. R. Henson	117
Nine waterspouts near Equator	117
Forecasting mean winter temperatures for the North American interior. C. F. Brooks	117
NOTES, ABSTRACTS, AND REVIEWS—Continued.	
Air-mail pilot encounters severe thunderstorm in Florida. James W. Smith	117
Speed record airplane flight	118
Pilot Wheaton's experience against terific head winds. L. A. Warren	118
Changes in the daily weather report of the London Meteorological Office	118
Climatic cycles in the Eocene. E. R. Miller	118
Padua (Italy) precipitation, 1901–1928, inclusive	119
Meteorological summary for Chile, for February, 1930. J. B. Navarrete. (*Transl. by W. W. R.*)	119
BIBLIOGRAPHY	119
SOLAR OBSERVATIONS	120
AEROLOGICAL OBSERVATIONS	121
WEATHER IN THE UNITED STATES	122
WEATHER ON THE ATLANTIC AND PACIFIC OCEANS	126
CLIMATOLOGICAL TABLES	130
CHARTS I–XI.	

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CORRECTION

Monthly Weather Review, Index, 1929:

Page XI, the entry "Reed, Charles D. Hail damage in Iowa. 189," should be deleted. The entry belongs to the preceding volume, No. 56.

MONTHLY WEATHER REVIEW

Editor, ALFRED J. HENRY

VOL. 58, No. 3
W. B. No. 1012

MARCH, 1930

CLOSED MAY 3, 1930
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THE CLIMATES OF ALASKA

By EDITH M. FITTON

[Clark University School of Geography]

CONTENTS

	Page
Introduction	85
I. Factors controlling Alaskan climates	86
II. Climatic elements	87
Sunshine, cloudiness, and fog	87
Temperature	89
Length of frostless season	90
Winds and pressure	90
January and July	91
Precipitation	92
Snowfall	96
Days with precipitation	96
III. Seasonal conditions in the climatic provinces	97
I A. Pacific coast and islands (marine)	98
I B. Pacific coast and islands (rain shadow)	99
II. Bering Sea coast and islands (semi-ice marine)	99
III. Arctic coast (ice-marine)	100
IV. Interior (cold continental)	101
Bibliography	102

INTRODUCTION

Popular opinion once pictured all Alaska as a frozen, treeless waste, inhabited only by polar bears and Eskimos, the latter living the year round in snow igloos and subsisting on seal meat. That such a description is more or less applicable to the tundra areas of the Bering and Arctic coasts can not be denied, but Alaska is too varied in relief, climate, and resources to be pigeonholed with a phrase. In complete contrast with the flat, treeless tundra is the bold, fiorded coast of the "Panhandle" whose scenic beauties of glacier and forested mountain side, coupled with cool summer temperatures, have made of it a summer goal for an increasing number of tourists each year. In contrast again is the broad interior plateau region, drained by the mighty Yukon, where long hours of sunshine bring summer temperatures high enough for grains and vegetables to ripen and where berries are produced in abundance. Still further contrast is offered by the majestic mountain ranges which flank Alaska to north and south, the Alaska Range having the highest peak in all North America—Mount McKinley. Truly Alaska does not warrant a blanket description of any sort.

Many people have been attracted to Alaska—explorers, prospectors, settlers, and tourists. Its resources of gold and copper, seals, salmon, and scenery are the main support of the inhabitants, which according to the 1920 census numbered 55,061.

Of primary interest to prospective Alaskan travelers and settlers are climatic conditions. The two nations that have controlled Alaska have always been interested in its climate, because, being on the borderland for human habitation, the extremes that would have to be endured there were of special concern. Before 1867, when the United States purchased Alaska, Russian missionaries to the Eskimos kept weather observations at their various posts and Government officials kept records for Sitka, the Russian capital. Other nations, chiefly the English and Americans, early sent ships of exploration into Alaskan waters, and there are scattered meteorological records available for various points where these vessels wintered along Alaskan shores (**7**, p. 137).

After the United States purchased Alaska, the United States Army surgeons kept weather records in connection with the post hospitals. "In 1878 and 1879, soon after the organization of the United States Weather Bureau, first under the Signal Corps of the Army, later as a bureau of the Department of Agriculture, a few first-class observing stations, together with several voluntary stations of lower order, were established in Alaska" (**1**, p. 133). In 1917 an appropriation of $10,000 permitted the establishment of additional first-class observing stations in Alaska (**39**, p. 464), so that there are now 9 such stations, while 44 cooperative observers bring the total up to 53 weather stations. The cooperative observers include United States experiment stations, radio stations, mining and railway companies, and religious missions as well as individuals.

The present study is an attempt to bring up to date the climatic data available for Alaska. Cleveland Abbe, jr., publishing in 1906 a section on climate in Alaska as part of Professional Paper No. 45, U. S. G. S. (**1**, p. 134), summarized the records used in his report as follows:

> The observations made up to the end of 1877 have already been summarized by Dall and Baker, and published, together with a very full bibliography, by the Coast and Geodetic Survey. The results of observations made at six United States Army posts, from 1861 to 1871, and the continuous series of Russian and American observations at Sitka, from 1847 to 1874, have been summarized by C. A. Schott, and published in two volumes by the Smithsonian Institution. They form valuable supplements to the earlier monograph by Dall and Baker. * * * The material summarized in the accompanying tables was taken from the manuscript records covering the period from 1868 to the present time, in the custody of the United States Weather Bureau. * * * These records were made by observers who may be grouped in four classes—post surgeons at regular United States Army posts, regular Signal Service or Weather Bureau observers, voluntary observers supplied by the Weather Bureau with instruments, and members of various expeditions.

In 1925, Melvin B. Summers, Alaska section director of the United States Weather Bureau at Juneau, published a Summary of the Climatological Data for Alaska, by Sections incorporating data from the establishment of the stations through 1921 (**29**). The present study makes use of these and other sources, as well as Climatological Data for Alaska, both monthly and annual publications (**37**), and some manuscript data supplied by the Weather Bureau.

Although the data are practically complete through 1927, a survey reveals the fact that only 29 stations have adequate records averaging over 10 years and covering (besides rainfall and temperature) wind direction, frost

period, days with rain, snowfall, clouds, and so forth. Even these data are not for the same series of years in many cases, but in spite of the seeming inadequacy of the records they are much fuller than those available when former studies were made for they cover a longer and more nearly consecutive period of years.

I. FACTORS CONTROLLING ALASKAN CLIMATES

The title of this paper, The Climates of Alaska is used advisedly for Alaska, has no climatological homogeneity. Regions adjacent on the map are found to have widely different climatic characteristics and it is the study of these striking contrasts and the reasons for them that lend the major interest to Alaskan climatology.

The continuation of the North American Coast Ranges in Alaska and the Alaska Range bear the chief responsibility for this contrast in climate between the Pacific coast and the interior. The Alaska Range attains heights of over 20,000 feet and the whole of southeastern Alaska is backed by ranges of between 5,000 and 10,000 feet. Such high mountains effectively interrupt the surface atmospheric circulation; hence in Alaska, they cut off the interior from the winds off the Pacific, thereby concentrating precipitation on the coast and decreasing it in the interior; at the same time they prevent the oceanic winds

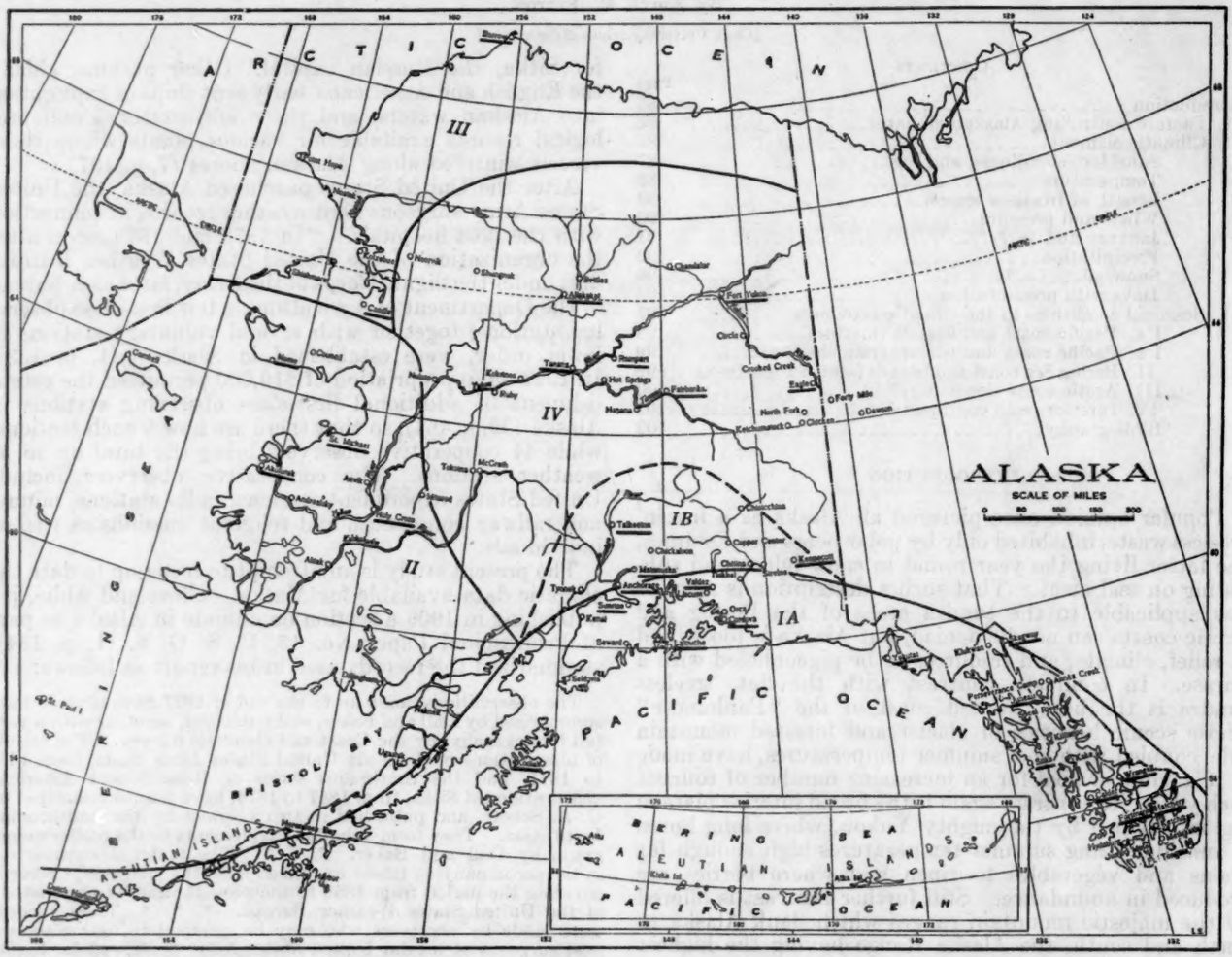

FIGURE 1.—Map of Alaska showing climatic provinces and the stations (underlined) used in the study

The climatic provinces into which Alaska has been divided and the location of the climatological stations therein are shown in Figure 1.

The Pacific coast and islands region is marked by heavy rainfall, the rest of Alaska by little; the Pacific coast rainfall has a cold season maximum, the precipitation over the rest of Alaska has a summer maximum; the Pacific coast is equable, the interior extreme, in temperature characteristics. It is evident then that Alaska presents a marine climate along its Pacific border and a continental climate over the rest of its area.

from moderating the temperatures of the interior and hinder the passage of winter cold winds from the interior to the coast.

Back of the Coast and Alaska Ranges is a rugged plateau region of 1,000 to 2,000 feet elevation, stretching northward to the Brooks Range. This range was crossed several times by Wilkins (42, p. 530) in his air flights from Fairbanks to his base at Point Barrow preparatory to his exploratory trip that culminated in his famous flight from Alaska to Svalbard (Spitsbergen). He found the mountains to be approximately 10,000 feet high, or about 5,000 feet higher than was previously supposed. They, as well as the Alaska Range, play their part in keeping oceanic influences out of the interior, and consequently the wide

Yukon Valley has the coldest and hottest temperatures in all Alaska and only a meager precipitation.

Beyond the Brooks Range a coastal plain about 50 miles in width slopes to the Arctic Ocean. The interior plateau slopes from its elevation of 5,000 feet just over the Canadian boundary gradually westward and finally disappears under the Bering Sea; the Coast Ranges also gradually decrease in height to the westward but maintain their identity far out into the ocean as the volcanic chain of the Aleutian Islands.

This chain of islands, by interrupting the free circulation of Pacific waters, and especially by deflecting the Alaska current, the eddy of warm water from the Japan current drift which bears northward and westward along the coast in the Gulf of Alaska, allows the Bering Sea to stay colder than it might otherwise be, which in turn affects the climate of its coasts. The Bering Sea, being almost inclosed, freezes over much of its area during the winter (17) and, as snow-covered ice becomes almost like an extension of the land, takes on continental climatic characteristics. (Fig. 1.) The same is true to an even more striking degree of the almost completely and thickly ice-covered Arctic Ocean.

Some tempering effect of the sea is still felt, however, for the unfrozen water beneath the ice gives off more heat to the surface than would be conducted from below to surface ice covering a land area, and hence ice temperatures over the sea never reach such a low minimum as those over the land. Furthermore, the occasional "leads," exposing open water to the winds, moderate somewhat the coldness which those winds may carry onto the coasts. Minimum temperatures of −70° F. have been recorded in interior Alaska, but −56° F. seems to be the lowest for Point Barrow on the Arctic coast. Winds from these frozen seas in winter carry so little moisture that the Bering and Arctic coast regions, in spite of marine location, have a continental summer maximum of precipitation.

The Japan current drift and its Alaska Gulf eddy bring warmer water to the Pacific coast than would normally be found at this latitude, thus magnifying the moderating effect of the ocean winds on winter temperatures and increasing the moisture content of the on-shore winds.

One other factor important in Alaska's climates is duration of sunshine, which, as determined by Alaska's latitudinal extent from 52° N. to 71° N., is quite different in the north from that in the south. The third of Alaska which lies north of the Arctic Circle has no sunshine at all about December 21 and very little during any of December or January, while in corresponding parts of June and July it has almost or quite 24 hours a day. All of Alaska is far enough north to experience a wide range in daily hours of possible sunshine during the course of a year and temperature, convection, winds, and consequent precipitation are affected accordingly.

Duration of sunshine, mountain ranges, and surrounding seas, then, may be called the chief factors in Alaska's climates. What effect they have on the various climatic elements is discussed in the next section of this paper.

II. CLIMATIC ELEMENTS

SUNSHINE, CLOUDINESS, AND FOG

The daily hours of sunshine possible for different latitudes across Alaska vary from none to almost 8 hours in December and from 16 to 24 hours in June (5). But the percentage of the possible hours which is actually received is generally quite low in Alaska. If the figures for Juneau are compared with those for Boston (36) the striking fact is brought out that in no month does Boston's percentage of possible hours of sunshine received reach as low a figure as the highest for Juneau. Nor does Juneau, even in the long days of summer when its possible hours of sunshine are 17 or 18 a day, ever equal Boston in actual hours of sunshine month by month. Boston has a yearly total almost twice that of Juneau, though both places have, of course, practically the same yearly amount of possible sunshine. And yet Boston has a rather low percentage of sunshine in comparison with most of the United States (31, p 33), which makes apparent the excessive cloudiness of Juneau and presumably of the whole Pacific coast section of Alaska for which Juneau may be taken as representative. A very low percentage of possible hours of sunshine in the month of October is of interest and will be found to correspond to the month of heaviest rainfall in this part of Alaska.

Figures 2 to 6 show graphically for each of the climatic provinces the monthly distribution of clear, partly cloudy, and cloudy days, also the number of days with rain and with snow, the depth of snow in inches and the amount of precipitation in inches, and other data.

No station in the interior of Alaska has data on sunshine, but an examination of that for Swede Creek in the upper Yukon Valley in Canada shows that March, April, June, July, August, and October all have a higher percentage of sunshine than Juneau, but again every month has a lower per cent and a lower actual amount than Boston. However, Swede Creek has a total number of actual hours greater than that of Juneau in spite of one month of complete darkness, which indicates that the interior of Alaska (taking Swede Creek as representative of it) has more sunshine than the Pacific shores. This fact will now be brought out again in the study of the clear and cloudy days and days with precipitation throughout Alaska.

Since the actual number of hours of sunshine is available only for Juneau, the number of clear and cloudy days gives the best basis for the other Alaskan stations from which to deduce the probable amount of sunshine received during the month as compared with the possible amount. For practically all Alaskan stations the number of clear days is seldom over half the month and oftentimes less than one-third. The greatest number of clear days is found in the interior and along the Arctic coast, especially during the late winter and early spring months. Clear skies are to be expected there at this time considering the small amount of vapor that can be present during the cold weather of winter.

All Alaskan stations except three or four in the interior average more cloudy days than clear ones in the course of the year. The Pacific coast is much the most cloudy part of Alaska with 200 cloudy days a year; interior and Arctic coast stations average under 150. More moisture is available to the Pacific coast region for the formation of clouds, while the coldness and dryness of the interior and of the Arctic shores makes fairly clear weather more usual there.

The Panhandle stations, as would be expected, show a higher percentage of cloudiness in all months than other stations in Alaska, and have a winter rather than a summer or fall maximum of cloudiness as the rest of Alaska has.

Records for foggy days are not available for any station in Alaska except Juneau (see footnote 1) which reports only one or two days of fog each month. This is surprisingly low considering the emphasis laid on fogs by travelers who write about the region. However, the monthly pilot charts of the North Pacific Ocean (35) show from 15 to

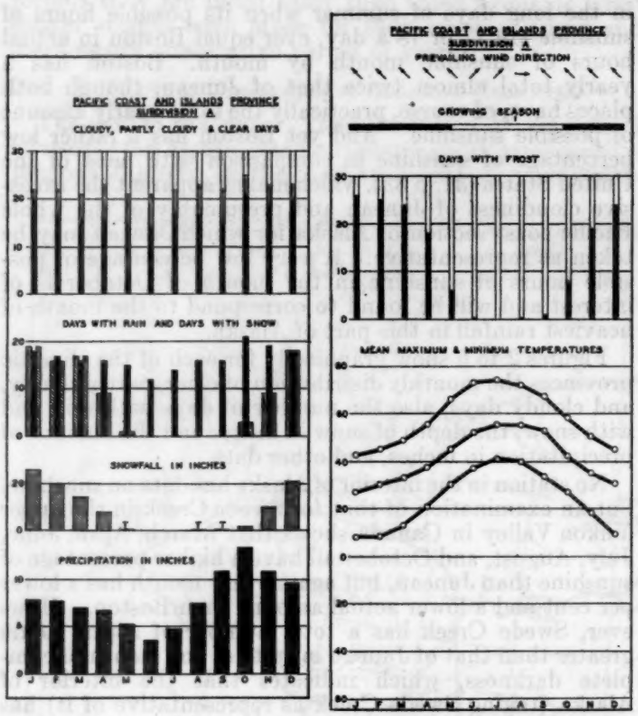

FIGURE 2.—Graph of climatic data for Pacific coast and island province, subdivision A

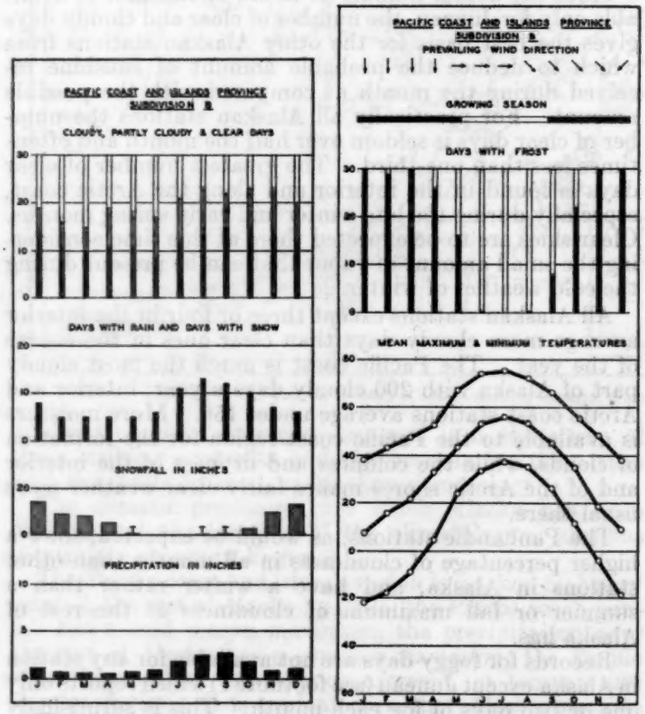

FIGURE 3.—Graph of climatic data for Pacific coast and islands, subdivision B

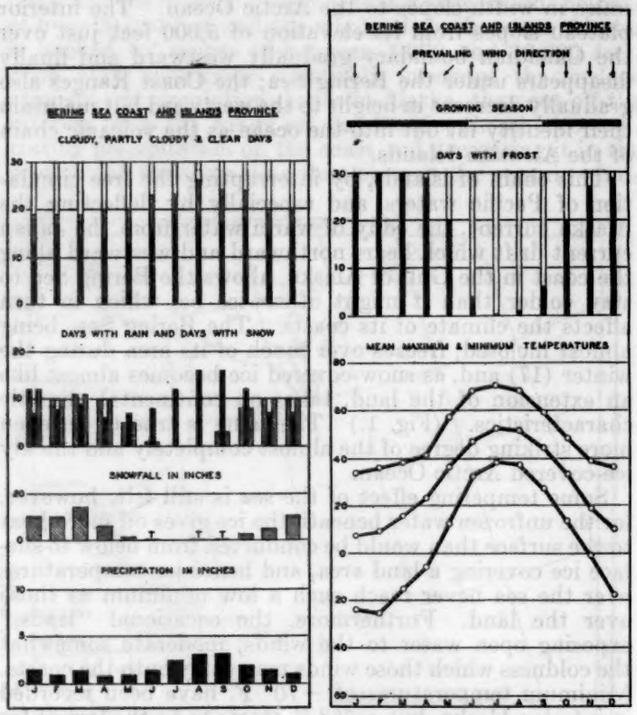
BERING SEA COAST AND ISLANDS PROVINCE
CLOUDY, PARTLY CLOUDY & CLEAR DAYS
DAYS WITH RAIN AND DAYS WITH SNOW
SNOWFALL IN INCHES
PRECIPITATION IN INCHES
BERING SEA COAST AND ISLANDS PROVINCE
PREVAILING WIND DIRECTION
GROWING SEASON
DAYS WITH FROST
MEAN MAXIMUM & MINIMUM TEMPERATURES

FIGURE 4.—Graph of climatic data for Bering Sea coast and islands

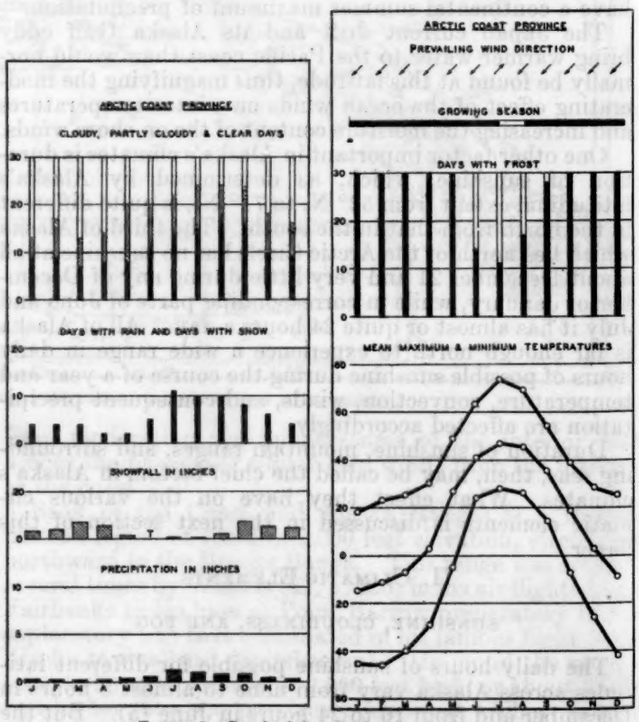

FIGURE 5.—Graph of climatic data for Arctic coast

25 per cent of the days as foggy in the Gulf of Alaska and about the Aleutian Islands during the winter season, which more nearly corroborates the statements of travelers. The warm winds off the ocean, blowing onto a colder land during the winter season, certainly would be conducive to a foggy condition so that probably this phenomenon is more common, on the outer coast at least, than Juneau's record of only one or two foggy days a month would indicate. Juneau probably has its low record because it is protected by intervening islands from the full effect of damp winds from the open ocean.

Unfortunately no records are available on which to base any definite statement regarding fog conditions over the rest of Alaska. Dawson, in Yukon territory, however, probably indicates fairly well the fogginess of the interior plateau of Alaska. The summer months are least foggy, early fall and winter most so, for the colder temperatures tend to cause condensation of what moisture the atmosphere may contain.

Fog is probably fairly frequent along the Bering Sea coast and Wilkins mentions heavy fogs around Point Barrow [1] as well as in the Yukon Valley in the spring season (42). All the seasons have conditions favorable for fog formation along the Arctic and Bering coasts; spring and summer bring a contrast between warm land and cold water and fall and winter bring a contrast between cold land and warm water. Open water in the northern seas, being of great extent only in summer and early fall, would tend to increase fogginess in those seasons along the coasts, for more moisture would then be available.

TEMPERATURE

Alaska, warmer during the year than is normal for its latitude along its Pacific coast but with that warmth shut off from the interior regions by high mountain ranges, naturally presents quite a wide difference in mean annual temperature between its north and south portions, though the distance is only about 800 miles. High relief is the chief contributing factor here, for in regions of similar latitudes but of low relief no such difference as 30° in mean annual temperatures is found. (Fig. 7.) For instance, in the Mackenzie Valley, Fort McPherson, north of the Arctic Circle, has a mean annual temperature of 14.1°, while Fort McMurray, 750 miles south in the same lowland, has a mean annual temperature of 30.3°, the difference being only 16.2° (6). In the Union of Socialist Soviet Republics similar temperatures for Archangel and Moscow are 32.4° and 38.5°, respectively, a difference of only 6.1° (43).

Examination of the annual temperature map of Alaska (fig. 7) shows that stations in the Alexander Archipelago, around the open parts of Prince William Sound, and on the southern shores of Kodiak Island all have annual temperatures over 40°. Slightly lower temperatures are found along the Pacific coast where the glaciers from the St. Elias Range descend to the sea.

The annual map shows that from the Pacific coast the temperatures decrease northward to the Arctic Ocean, the 5° isotherms forming fairly parallel bands east and west across Alaska. It is evident from a comparison of the January and July maps (figs. 8 and 9) that this fairly homogeneous decrease is due almost wholly to the conditions that prevail during the winter, for in summer there is an increase in temperature in going north, at least as far as the Yukon Valley. However, the contrasts in temperature during the winter months are evidently enough to overbalance the approaching equalities of the summer months, for the annual map shows an average difference of 30° for the entire year.

Eleven 5° isotherms are required in January to show the difference of temperature across Alaska from over 30° on the Pacific coast to less than −20° in the interior and on the north coast, while on the July map the four isotherms, 45° to 60°, suffice to show the whole temperature range. Of especial interest is the crowding of the January isotherms along the Pacific coast, showing the rapid decrease in temperature back of the coastal mountains which shut off the interior from the moderating influence of the ocean.

On the July map the tendency of the 5° isotherms to encircle the interior is of interest; the center and hottest

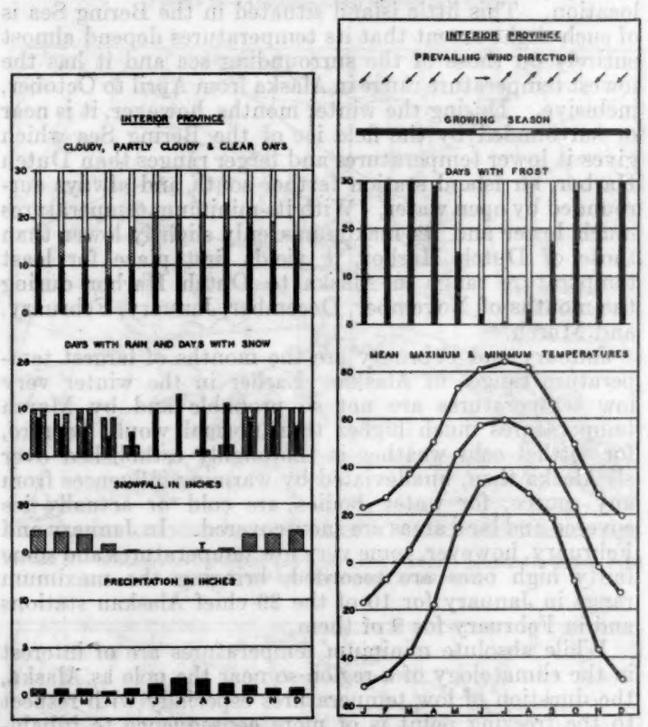

FIGURE 6.—Graph of climatic data for the interior

region is the Yukon Valley, with a decrease of temperature in all directions toward the various coasts. This demonstrates very well the greater heating of land bodies as opposed to water bodies, especially when those land areas are cut off from cooler ocean winds by intervening mountain ranges.

The greatest ranges of temperature, both absolute and annual, are found in the interior of Alaska. Eagle has the greatest range of any single station, with an absolute maximum of 95° F. and a minimum of −69° F., the range being 164°. Allakaket has a lower minimum than Eagle, −70°, and Fairbanks has a higher maximum, 99°; but the ranges at these two stations are less, being 160° and 156° respectively. Verkhoyansk, Siberia, and Fort Good Hope, Canada, regions of similar geographic character except that, due to their position with regard to prevailing winds, they are even less subject to oceanic influences than

[1] The author evidently did not have access to the report of the International Polar Observations made at Point Barrow from November, 1881, to Aug. 27, 1883. These observations show that in winter months, November to March and April, fog is infrequent but there is a very considerable amount of haze which at times is so dense as to be mistaken for fog. The fog season at Point Barrow, judging from but two seasons, 1882 and 1883, begins in May and continues through September. In the 5 months, May to September, 1882, dense fog was reported on 43 days with a total duration of 240 hours. In the next following season or rather up to Aug. 27, 1883, dense fog was reported on 45 days with a duration of 270 hours; in August, 1883, lacking 4 days, dense fog occurred on 15 of the 27 on which observations were made. It is also apparent from the record for this station that light drizzling rain often continues for a number of hours consecutively, thus making visibility very poor.—A. J. H.

Eagle, have greater absolute ranges, the figures being 183° and 172° respectively (**15**, p. 176, and **6**).

Figure 10, showing the absolute yearly temperature ranges in Alaska, illustrates very well the fact that increasing distances from the equable ocean waters cause greater temperature extremes. A range of under 100° occurs all along the immediate Pacific coast, and even the Arctic Ocean and the Bering Sea, though frozen over entirely or partially during much of the year, moderate somewhat the temperatures of the adjacent coasts, and thus the greatest ranges are found in the interior. This region is shut off by mountain ranges from winds off the surrounding water bodies and so is not warmed by them in winter nor cooled by them in summer. Furthermore, the lesser water vapor and clearer skies of this inland region allow greater cooling by radiation on calm winter nights and greater heating by insolation on long summer days than do the higher absolute humidities and cloudier skies of the coastal regions.

St. Paul Island is the station par excellence to illustrate the equability of temperatures resulting from a marine location. This little island situated in the Bering Sea is of such slight extent that its temperatures depend almost entirely on those of the surrounding sea and it has the lowest temperature range in Alaska from April to October, inclusive. During the winter months, however, it is near or surrounded by the field ice of the Bering Sea which gives it lower temperatures and larger ranges than Dutch Harbor, an island station farther south and always surrounded by open water. With its minimum temperatures much lower and its maximums only slightly lower than those of Dutch Harbor, it yields first place for least temperature range in Alaska to Dutch Harbor during the months of November, December, January, February, and March.

January and February are the months of largest temperature ranges in Alaska. Earlier in the winter very low temperatures are not so probable and by March temperatures much higher than normal would be rare, for settled cold weather is thoroughly established over all Alaska then, unalleviated by warming influences from any source, for water bodies are cold or actually ice covered and land areas are snow covered. In January and February, however, some very low temperatures and some fairly high ones are recorded, bringing the maximum range in January for 10 of the 29 chief Alaskan stations and in February for 9 of them.

While absolute minimum temperatures are of interest in the climatology of a region so near the pole as Alaska, the duration of low temperatures especially with respect to the freezing point is of more consequence to inhabitants of such a region. "Frost days," those days during the course of which the minimum temperature falls at least as low as 32°, are numerous in Alaska, though Barrow, Eagle, and Fort Yukon are the only three stations having frost days in every month, while Fortmann Hatchery, Sitka, and Yakutat, with four months having no frost days, stand at the other extreme. Barrow, with an average of 324 frost days, has the greatest yearly number, while Juneau and Sitka, each with only 106, have the smallest. The Pacific coast stations and St. Paul Island have some days each month even in the winter when the temperature does not fall to freezing, while over all the rest of Alaska practically every day from November, to March, inclusive has freezing temperatures. Here again the moderating influence of the warmer Pacific Ocean is apparent.

The length of the frostless season, being dependent on the frost dates, is, of course, longer along the Pacific coast. However, the long hours of sunshine and great heating of the interior plateau make the shorter growing season of this region sufficient for grains, vegetables, and many berries. The period without killing frost is generally over 140 days (4½ months) on the Pacific coast; about 100 days (slightly over 3 months) on the Bering Sea coast; only about 35 days (1 month) on the Arctic coast; and 80 days (not quite 3 months) in the interior plateau.

"Ice days" are those when the temperature is never above 32°.[2] The contrast between the Pacific coast and the rest of Alaska is again apparent, the coast averaging about 40 such days in a year while all the rest of Alaska, with the exception of two stations with marine location on the Bering Sea, Dillingham, and St. Paul Island, has over 100 ice days a year, the maximum being an average of 253 at Barrow. Nome, Eagle, and Tanana, representative of the Bering Sea coast and interior Alaska, have almost entire and sometimes entire months of such weather from November to March, inclusive, whereas Juneau, representing the Pacific coast, never averages more than 14 such days a month and has over 10 days only in December and January.

From the point of view of temperature the Pacific coast region of Alaska has extreme cold no more unbearable than that found over much of the United States, while the yearly temperatures have a more moderate range, being influenced in this respect by the marine location, than many parts of the United States. The interior region of Alaska averages much colder than the United States, but the fact that there is little moisture in the air during the winter season probably helps to make the cold bearable, while the rather high summer temperatures relieve the monotony of continuous cold under which more marine locations in these northern latitudes suffer.

WINDS AND PRESSURE

The January and July sea level pressure maps show the general winter and summer pressure distribution over Alaska. (Figs. 11 and 12.) During the winter season the cold land and the polar ice cap, by greatly chilling and contracting the air, develop an area of high pressure, while by contrast the warmer Pacific Ocean causes expanding air and low pressure, resulting in the so-called Aleutian LOW, which has generally been thought to be the source of the great majority of the winter cyclones of North America. However, recent study of meteorological reports received from the Asiatic coast and islands and vessels crossing the Pacific has led to the conclusion that the cyclonic storms entering North America from the northwest originate far beyond the Aleutian Islands, the permanent Aleutian LOW simply affording a favorable channel through which the disturbances pass, rather than being their breeding place (**19**, p. 134).

The intensity of the winter-low pressure area seems to be in large part dependent upon the temperature of the North Pacific waters, and especially on the temperature gradient from a few hundred miles at sea to the shore. Several years ago the Canadian Meteorological Service equipped four of the ships of the Canadian Pacific Steamship Co. with thermographs for recording the temperature of the surface water between Vancouver and Yokohama in an attempt to determine the relationship between water temperature and the intensity of cyclonic development. While detailed results have not been obtained as yet, it would seem that the warmer the Pacific waters are the more favorable are conditions for deep cyclonic depres-

[2] Ice days are commonly defined as those when the temperature does not rise to 32°, but here the difference in definition is of no consequence since temperatures to the nearest tenth of a degree were used in the Weather Bureau tabulations.

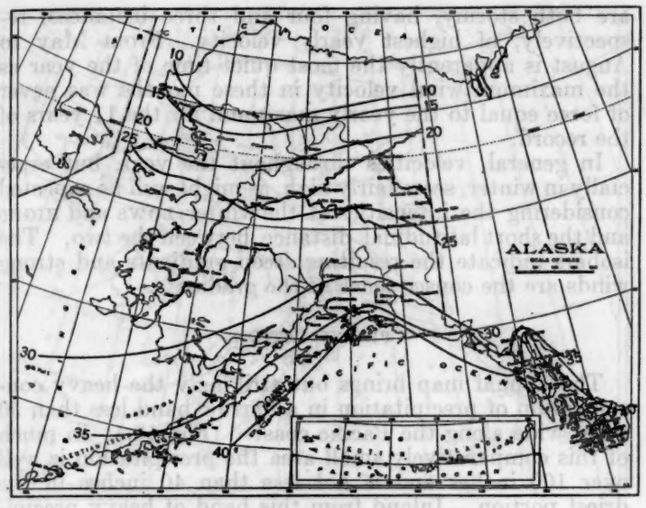

FIGURE 7.—Mean annual temperature

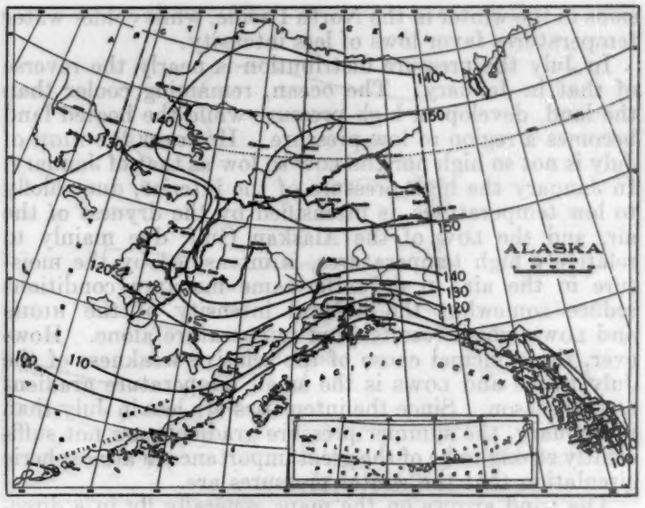

FIGURE 10.—Absolute annual temperature range

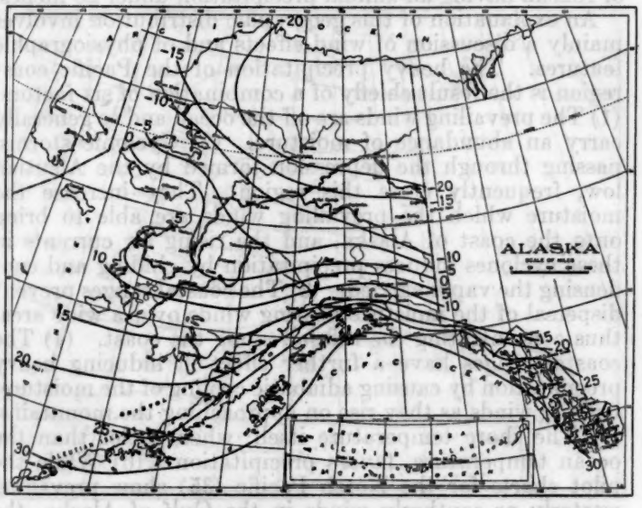

FIGURE 8.—Mean January temperature

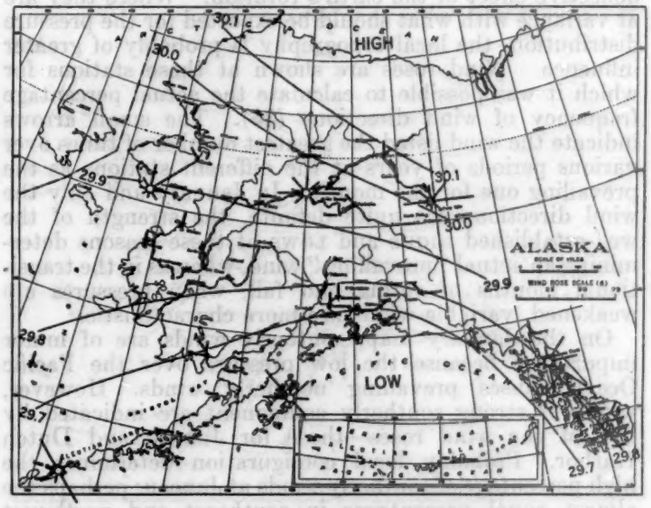

FIGURE 11.—Mean sea level pressure and wind roses, January; pressure in inches, wind frequency one-half inch equals 25 per cent

FIGURE 9. Mean July temperature

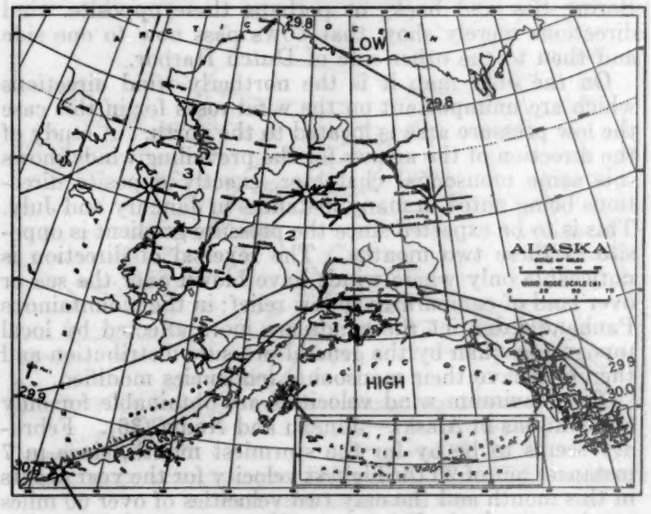

FIGURE 12.—Mean sea level pressure and wind roses, July; pressure in inches, wind frequency one-half inch equals 25 per cent

sions in the winter in the North Pacific, while colder water temperatures favor lows of less intensity.

In July the pressure distribution is nearly the reverse of that in January. The ocean, remaining cooler than the land, develops a high pressure while the heated land becomes a region of low pressure. However the HIGH of July is not so high nor the LOW so low as that of January. In January the high pressure of the interior, due chiefly to low temperatures, is intensified by the dryness of the air, and the LOW of the Alaskan Gulf, due mainly to relatively high temperatures, is intensified by the moisture in the air; in July the same moisture conditions reduce somewhat the natural intensity of the HIGHS and LOWS which results from temperature alone. However, the principal cause of the relative weakness of the July HIGHS and LOWS is the small temperature gradient at this season. Since the intensities are less in July than in January, the summer pressure gradients are not sufficiently strong to be of the great importance in atmospheric circulation that the winter pressures are.

The wind arrows on the maps generally fly in a direction in accordance with the pressure distribution and the deflective effect of the earth's rotation. Where they are at variance with what should be expected for the pressure distribution, the local topography is probably of greater influence. Wind roses are shown at those stations for which it was possible to calculate the actual percentage frequency of wind directions (**36**). The small arrows indicate the wind listed the greatest number of times over various periods of years at the different stations as the prevailing one for the month. In January and July the wind directions are quite definite, the strength of the well-established HIGHS and LOWS at these seasons determining an actual "prevailing" wind, whereas in the transitional months of spring and fall, when pressures are weakened, variable winds are more characteristic.

On the January map, southerly winds are of minor importance because the low pressure over the Pacific Ocean causes prevailing northerly winds. However, winds of strong southerly component are indicated by two of the wind roses—those for Juneau and Dutch Harbor. Probably local configuration determines the high percentage of southerly winds at Juneau; perhaps the almost equal percentages in southeast and northwest directions at Dutch Harbor indicate occasional shiftings of the low pressure area from the Pacific Ocean to the Bering Sea and back; or perhaps these opposite wind directions merely show that LOWS pass now to one side and then to the other side of Dutch Harbor.

On the July map it is the northerly wind directions which are unimportant on the wind roses for in this case the low pressure area is located to the north. A study of the direction of the arrows for the prevailing winds shows this same monsoonal character, exactly opposite directions being noted in many instances in January and July. This is to be expected since the pressure gradient is opposite in these two months. The reversal of direction is noticeable only where winds have blown over the sea or over land of comparatively low relief; in the mountainous Panhandle district the winds are more affected by local topography than by the general pressure distribution and therefore have their monsoonal tendencies modified.

The maximum wind velocities are obtainable for only two stations in Alaska—Juneau and Nome (**36**). February seems to be by far the stormiest month, since in 7 instances out of 20 the highest velocity for the year occurs in this month and the only two velocities of over 60 miles per hour occur in February. November and December are both stormy, having four and three instances, respectively, of highest yearly velocity. From May to August is apparently the most quiet time of the year as the maximum wind velocity in these months was never of force equal to the yearly maximum for the 11 years of the record.

In general, velocities throughout the year, but especially in winter, seem fairly high, as might well be expected considering the intensities of the winter LOWS and HIGHS and the short latitudinal distance between the two. The isobars indicate the resulting steep gradients and strong winds are the consequence of the gradients.

PRECIPITATION

The annual map brings out strikingly the heavy concentration of precipitation in a narrow band less than 50 miles wide along the Pacific coast. (Fig. 13.) In much of this comparatively small area the precipitation is well over 100 inches and is not less than 40 inches in the driest portion. Inland from this band of heavy precipitation the rainfall decreases rapidly, fully two-thirds of Alaska having an annual precipitation under 20 inches.

An explanation of this geographic distribution involves mainly a discussion of wind effects and of physiographic features. The heavy precipitation of the Pacific coast region is the result chiefly of a combination of six factors: (1) The prevailing winds are off the ocean and so generally carry an abundance of moisture. (2) Cyclonic storms, passing through the depression formed by the Aleutian low, frequently cross this region. They increase the moisture which the prevailing winds are able to bring onto the coast of Alaska, and the rising air currents in these cyclones induces precipitation by chilling and condensing the vapor carried. (3) The coastal ranges prevent dispersal of the moisture-bearing winds over a wide area, thus concentrating the rainfall along the coast. (4) The coastal ranges have a further effect in inducing heavy precipitation by causing adiabatic cooling of the moisture-bearing winds as they rise on approaching the mountains. (5) The shore temperature itself, when cooler than the ocean temperature, favors precipitation. (6) While the pilot charts for the North Pacific (**35**) show prevailing westerly or southerly winds in the Gulf of Alaska, the coast station records show frequent northerly or easterly winds. Those winds, blowing down valleys from the interior, are generally much colder than the winds off the Pacific. Consequently the warmer Pacific winds rise over the shore winds and precipitation results, both as a consequence of the cooling from increased elevation, and the mixing of the warm winds above with, and radiation to, the cold surface winds. The unusually heavy rainfall of 172 inches at Latouche is probably the result of the coming together here of cold interior winds and warm ocean winds.

The precipitation of the interior is reduced because of the concentration along the Pacific coast, but other factors also enter in. It is a region of high pressure during the winter months, with settling and outflowing winds, and consequent low precipitation at this season. Most of the rainfall comes in the summer in the form of convectional showers for the development of which the inflowing air from the sea, with wide extent of land, and long hours of summer sunshine are favorable. When northerly or westerly winds do blow across the interior they are not able to precipitate much moisture, because, being from cold, ice-hemmed seas, their moisture content is slight.

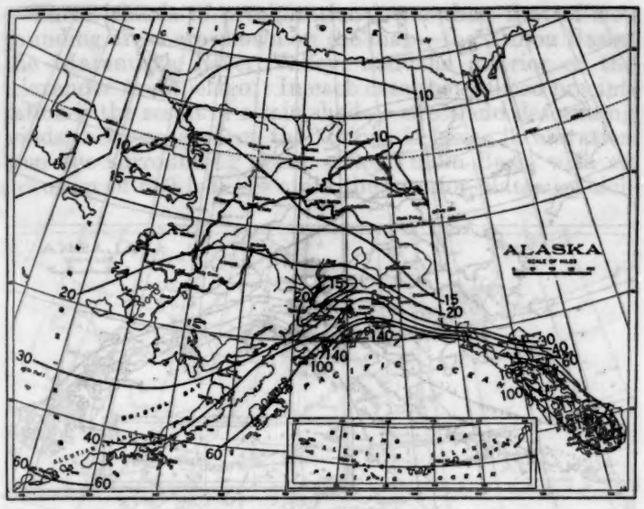

FIGURE 13.—Mean annual precipitation

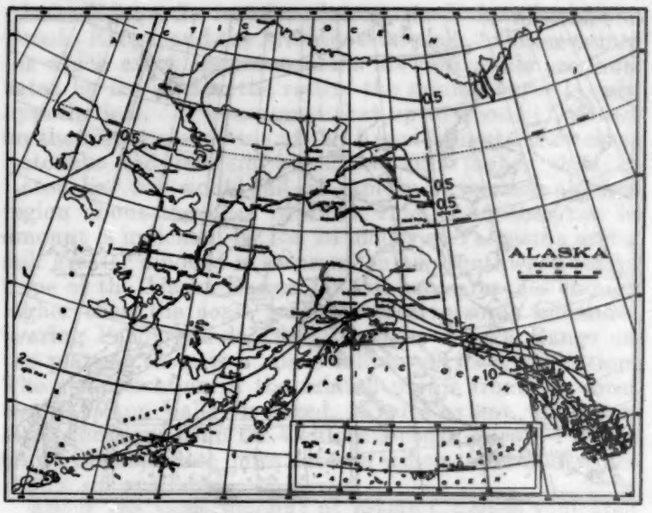

FIGURE 16.—Mean precipitation, March

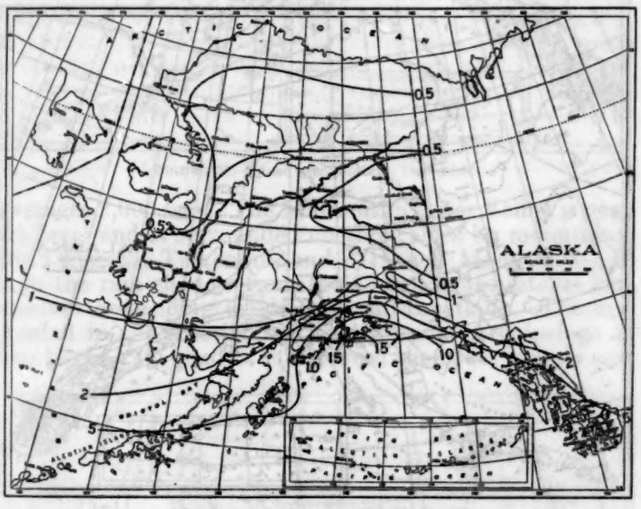

FIGURE 14.—Mean precipitation, January

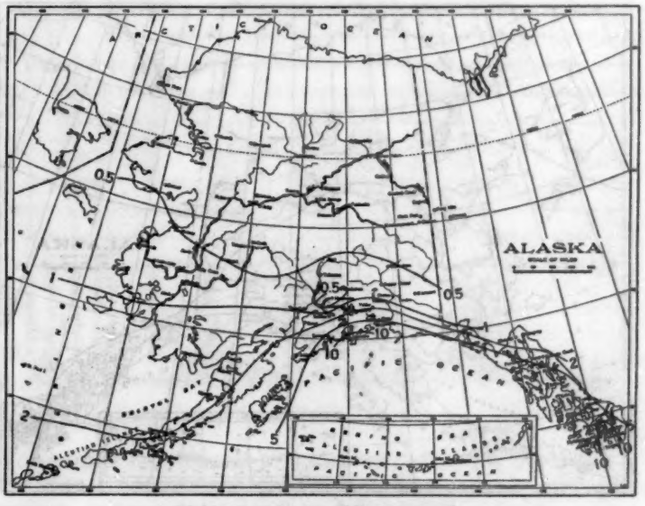

FIGURE 17.—Mean precipitation, April

FIGURE 15.—Mean precipitation, February

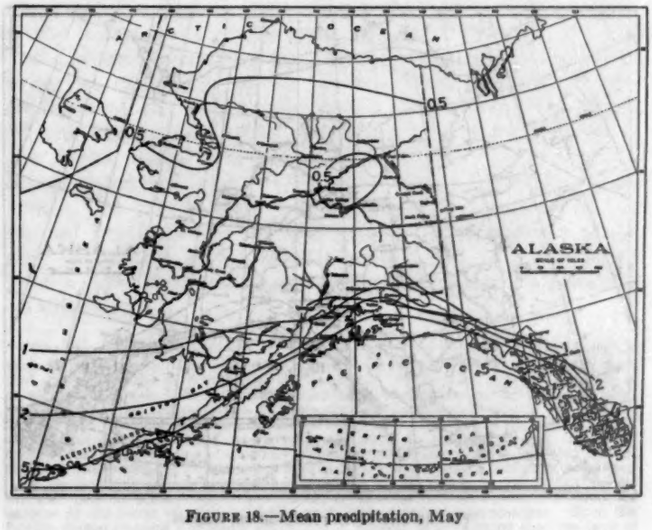

FIGURE 18.—Mean precipitation, May

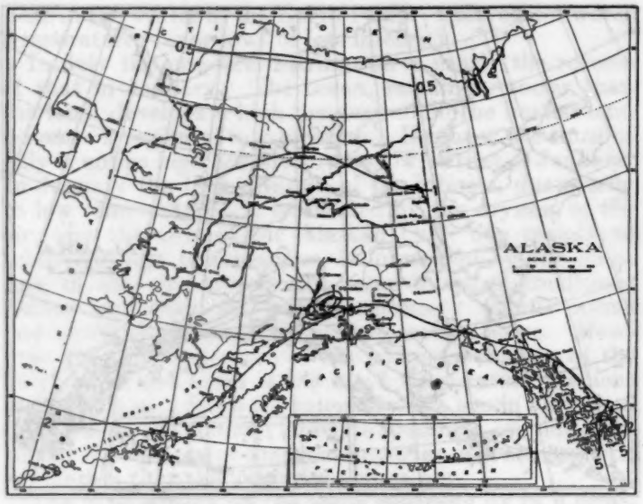

FIGURE 19.—Mean precipitation, June

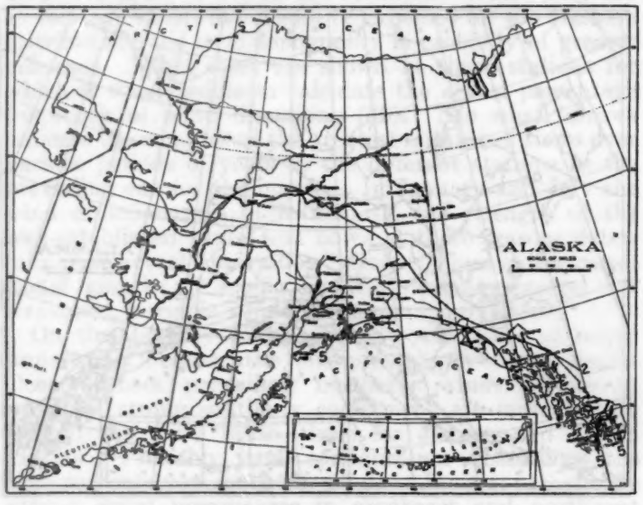

FIGURE 20.—Mean precipitation, July

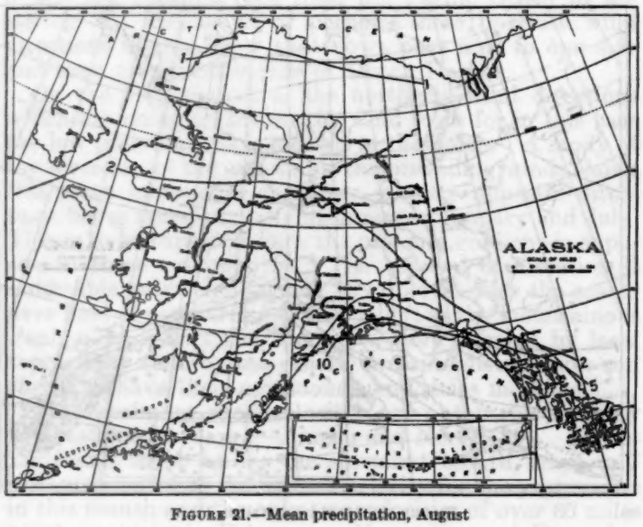

FIGURE 21.—Mean precipitation, August

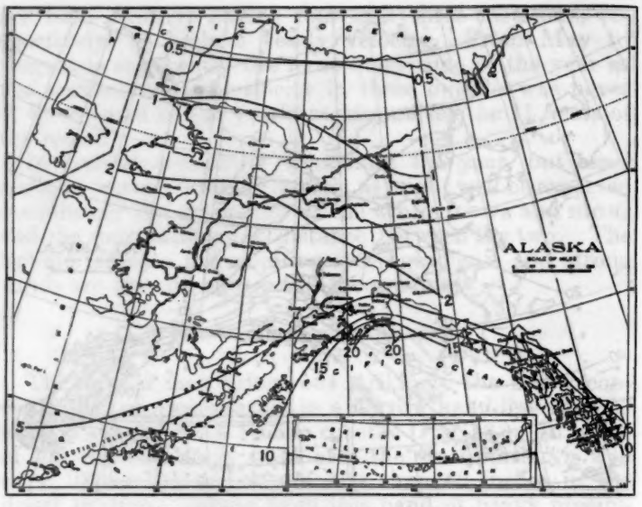

FIGURE 22.—Mean precipitation, September

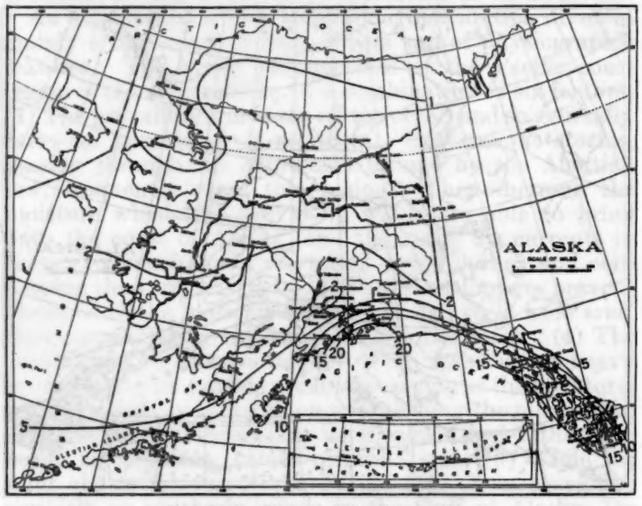

FIGURE 23.—Mean precipitation, October

FIGURE 24.—Mean precipitation, November

Three islands of precipitation lower than that of surrounding areas are shown on the map—the Yukon Basin, the Matanuska River Valley, and the interior of the Alexander Archipelago. In each case the reduced precipitation is the result of a rain shadow effect and descending winds, because each of the regions is lower in elevation than the surrounding areas. The Yukon Basin with an elevation of 500 feet lies amid the interior plateau which

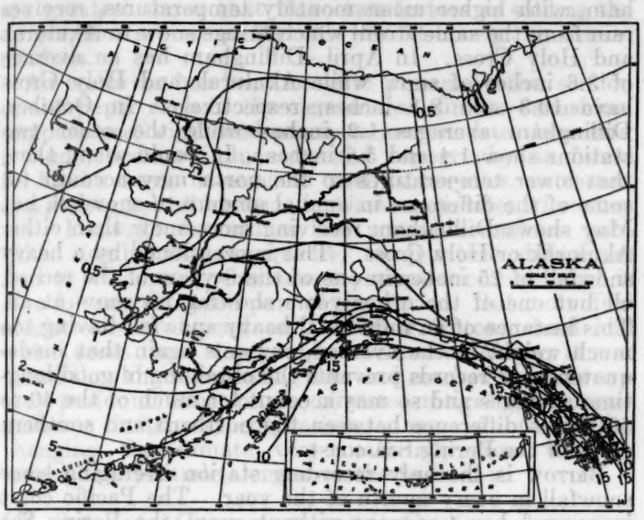

FIGURE 25.—Mean precipitation, December

averages 2,000 feet. The Matanuska River Valley is near sea level and is surrounded on three sides by mountains, the Chugach, Talkeetna, and Wrangell Mountains. It is in the rain shadow from the Chugach Mountains and receives descending winds from all directions. The low rainfall in the interior of the Alexander Archipelago is due to the rain shadow effect from the coast islands and

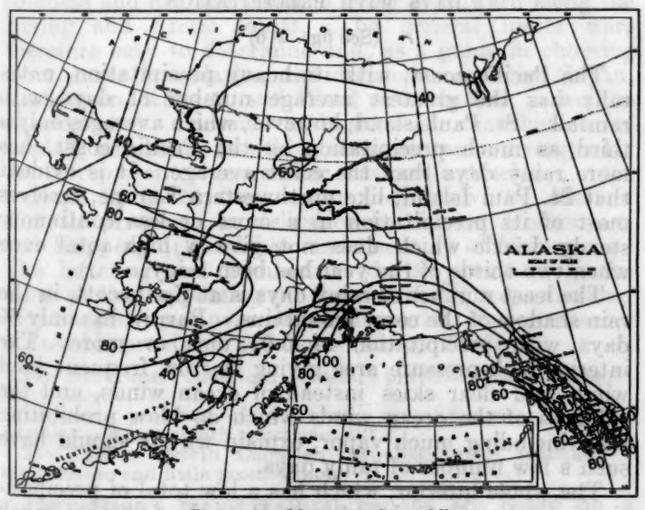

FIGURE 26.—Mean annual snowfall

to descending winds also from the eastward mountain ranges.

A generalized profile (fig. 27) extending directly north for 800 miles across Alaska from Latouche to the Arctic Ocean shows the great range in precipitation, from 172 inches to only 5 inches annually, and also brings out the effect of elevation on precipitation since it cuts across the Kenai Mountains, the Matanuska River Valley, the Alaska Range, the interior plateau, the Yukon Basin, the Brooks Range, and the Arctic coastal plain. Those points for which exact annual rainfalls are obtainable are indicated by the circles; the rest of the rainfall curve is only hypothetical. It is assumed that up to about 1,500 feet on the higher elevations of the Kenai Mountains back of Latouche the rainfall would be still higher than at Latouche,[3] but would fall off rapidly in the rain shadow region about the head of Cook Inlet. Another rise in amount is indicated by the 26 inches at Talkeetna and a still greater amount is assumed on the southward-facing slope of the Alaska Range, for this range reaches enough higher than the coast range to receive some moisture-bearing Pacific winds. North of the Alaska Range on the plateau there is a sharp falling off in precipitation. The generalization in the rainfall profile from the coast to the Yukon Valley is based, to some extent, upon parallel conditions from the California coast eastward to the Great Plains, where more data on which to base an exact profile are available.

About the same amount of precipitation is indicated across the whole interior plateau region. This seems to

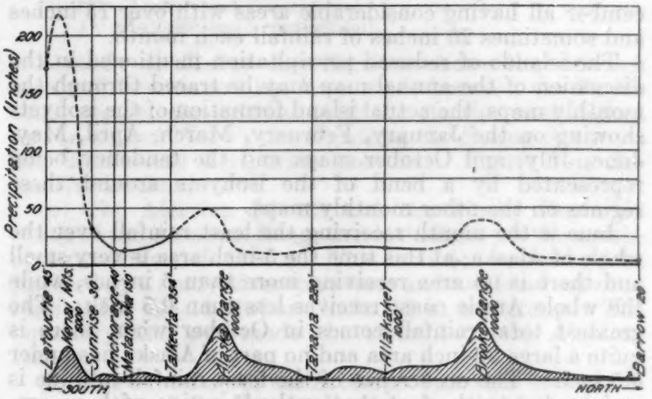

FIGURE 27.—Profile of precipitation north/south across Alaska

be justified because all the stations, of which two are on the direct north-south profile line, have annual precipitations varying no more than from 10 to 13 inches.

No actual figures for precipitation on the Brooks Range are available, but it is assumed that it would be relatively low in spite of the great height of the range. The north slope, depending on winds off the Arctic Ocean to bring in moisture, would receive little because of the coldness of the winds; the south slope, receiving winds off the Bering Sea, which are almost as much chilled as the Arctic winds and which, in addition, have crossed a broad extent of land, would also receive little precipitation. The profile shows, therefore, only about 35 inches annual precipitation for the range, the maximum probably occurring at an elevation of 4,000 to 5,000 feet,[4] with a rapid decrease in amount over the lower elevations on either side.

[3] The assumption is based on A. J. Henry's conclusions in Increase of Precipitation with Altitude. (MONTHLY WEATHER REVIEW, vol. 47, 1919, pp. 33-41.) Henry finds that on the Cascades in Washington the maximum precipitation apparently comes at an altitude of about 1,500 feet, though in Oregon the station on his west-east cross section, which has the maximum precipitation, has an elevation of only 575 feet. In Norway also the maximum is found at an altitude of 1,500 feet, Kvitingen, a station of that altitude, showing the maximum precipitation for all Norway (46). Since the Pacific coast of Alaska has geographic conditions resembling those in Washington and Norway, the maximum precipitation on the Kenai Mountains is placed at 1,500 feet.

[4] A special study of precipitation in Norway by H. W. Ahlmann (44) brings out the fact that summer time precipitation reaches its maximum at an elevation of 5,000 feet because of the lower relative humidity with high summer temperatures. Since the Brooks Range receives a summer maximum of rainfall, it is assumed that the zone of maximum precipitation on the range would be more or less in accord with that of Norway in the summer, the zone therefore being at approximately 4,000 or 5,000 feet.

The monthly rainfall maps again show the heavier precipitation along the Pacific coast. (Figs. 14–25.) It holds for every month of the year, but in July the precipitation contrast between the coast and the rest of Alaska is least and in September it is greatest. In July no place receives more than 5 inches nor less than 1 inch while in September a portion of the coast around Cordova receives over 20 inches and the Arctic coast receives less than 0.5 inch. In the summer time the HIGH in the Alaskan Gulf is conductive to on-shore winds so the rugged Pacific coast receives summer rainfall from that source as well as from the few and relatively weak cyclones which pass over the region; the amount, however, is by no means so great as the numerous cyclonic storms and great land and sea temperature contrasts of fall and early winter cause. On the other hand the rest of Alaska, becoming comparatively hot in July and August, causes convectional rainfall and this also at a time when the air is hottest and can include the most moisture. Therefore the most uniform rainfall distribution over Alaska is found in summer, especially in July.

The early fall months are seen to be the rainiest along the coast, September, October, November, and December all having considerable areas with over 15 inches and sometimes 20 inches of rainfall each month.

The islands of reduced precipitation mentioned in the discussion of the annual map may be traced through the monthly maps, the actual island formation of the isohyets showing on the January, February, March, April, May, June, July, and October maps and the tendency being represented by a bend of the isohyets around these regions on the other monthly maps.

June is the month receiving the least rainfall over the whole of Alaska; at this time the 5-inch area is very small and there is no area receiving more than 5 inches, while the whole Arctic coast receives less than 0.5 inch. The greatest total rainfall comes in October when there is quite a large 20-inch area and no part of Alaska has under 0.5 inch. The occurrence of the least rainfall in June is mainly due to the fact that cyclonic action with accompanying strong on-shore winds, is relatively weak at that season; the greatest rainfall in October comes when cyclonic action is strengthening and land and sea temperature contrasts are great.

SNOWFALL

Snowfall over Alaska is found to have a general distribution similar to the rainfall, as would be expected. (Fig. 26.) There is a heavy fall along the Pacific coast with a decrease northward to a minimum, as with total annual precipitation, along the Arctic coast.

It is along the Bering Sea coast that the snowfall map differs most decidedly from the rainfall map. The surprising variation in amount from under 40 inches around Dillingham to over 80 inches a short distance to the north is hard to explain. For one thing, the records are not long and are not for a uniform series of years so that the mean monthly and annual snowfalls are found to vary considerably. However, the annual snowfalls for the same years may be compared at Dillingham and Holy Cross as follows (**38**):

Inches of snow

	Dillingham	Holy Cross
1920	45.3	67.8
1926	19.2	43.2
1927	64.9	113.6
3-year average	43.1	74.9

These three years show consistently the great difference in the annual snowfalls and seem to indicate that the difference is an actual one rather than an apparent one due to inadequate records.

A further explanation for the difference may be found in the fact that Dillingham shows a less amount of snow in early winter and late spring than do Akulurak and Holy Cross to the north, presumably because Dillingham, with higher mean monthly temperatures, receives rain from the same storm which brings snow to Akulurak and Holy Cross. In April, Dillingham has an average of 3.6 inches of snow while Akulurak and Holy Cross have 10.3 and 8.1 inches, respectively. In October, Dillingham averages 1.2 inches while the other two stations show 1.4 and 5.8 inches. It would seem, then, that lower temperatures to the north may account for some of the difference in annual amount of snowfall, but May shows Dillingham receiving more snow than either Akulurak or Holy Cross. This is occasioned by a heavy snowfall of 25 inches in one of the 8 years of the record, all but one of the other years showing no snow at all. This instance of an individual heavy snowfall having too much weight in the average, suggests again that inadequateness of records prevents the obtaining of good long-time averages and so may account for much of the 40 to 50 inches difference between the northern and southern parts of the Bering Sea coast.

Barrow is the only recording station averaging some snowfall in every month of the year. The Pacific coast in general has 4 months without snow, the Bering Sea coast 3 months, the interior 2 months, and the far North no month without at least a trace of snow.

In the interior June and July are the months without snow while in the same latitude the Bering Sea coast has July and August free from snow, again illustrating the effect of a cold sea in retarding the maximum heating an increased number of weeks beyond normal after the highest sun.

DAYS WITH PRECIPITATION

(See figs. 2–6)

The Pacific coast, with its heavy precipitation, naturally has the greatest average number of days with rainfall. St. Paul Island, however, which averages only a third as much precipitation as the Pacific coast, has more rainy days than the coast average. It is evident that St. Paul Island, like northwestern Europe, receives most of its precipitation in a more or less continuous steady drizzle which does not give a high total even when two-thirds of the year has been rainy.

The least number of rainy days is at Kennecott, in the rain shadow of the coast mountains. Barrow has only 66 days with precipitation of 0.01 inch or more. The interior high-pressure area giving Barrow frequent land winds and clear skies instead of ocean winds, and the coldness of the ocean winds which do blow prohibiting their including much vapor, explain why it should have such a low number of rainy days.

The whole interior, which has a low total of precipitation, also has few rainy days. Here the fact that much of the precipitation comes in summer convectional showers, which tend to concentrate most of the rainfall for a month in a few showers, helps to explain the low number of rainy days.

The heaviest rainfalls in the course of 24 hours occur along the Pacific coast. The summer convectional showers of the interior seldom produce more than an inch of rain in any 24 hours and never as much as 2 inches, whereas the heavy and steady orographic and

cyclonic rains of the coast often produce 4 or 5 inches in 24 hours and sometimes as much as 9 or 10 inches. In one day the rainfall of the coast may equal or surpass the yearly total received at many stations in Alaska.

Those stations which are backed by high mountains have the heaviest rainfalls, but the fact that the greatest rains come in the fall and winter when cyclonic storms are frequent and land and sea temperature contrasts are greatest shows that these two factors as well as the orographic are amplifiers of the 24-hourly maximum rainfalls.

An endeavor has been made to present in this section of the paper each of the elements of climate—sunshine, temperature, wind, and precipitation—and to show how latitude, oceanic influences, and topography as found in Alaska have determined their intensities, extremes, and averages, and have made Alaskan climates what they are. Latitude determines the possible sunshine, sunshine dominates temperature, temperature differences lead to winds, and wind causes precipitation—so much is true for any extended part of the world. But individual characteristics depend on the other factors—land and water areas and topography; hence, in Alaska it was found that the surrounding seas and marked relief have a very profound effect on the climate, mitigating extremes in some instances, emphasizing them in others, but changing the climate very materially from what it would be if latitude alone were the basis of it.

III. SEASONAL CONDITIONS IN THE CLIMATIC PROVINCES

(See fig. 1 and figs. 2–6)

In undertaking a seasonal description of weather in Alaska it seemed best to organize the discussion around each of the several distinct climatic provinces into which Alaska naturally divides itself. There is an obvious contrast between the climates of the Pacific coast and the Yukon Valley and there is a gradual but increasing coldness and dryness found in going northward along the Bering and Arctic coasts. The general limits were therefore easy to determine and, as a guide in choosing more exact boundaries, the divisions made by Supan, Herbertson, Köppen, and Ward were studied, as well as physiography, amount and seasonal distribution of rainfall, and mean monthly temperatures and ranges for the 29 representative weather stations in Alaska.

Maps 22 to 24 (not reproduced) show the Alaskan climatic provinces as delimited by Supan, Herbertson, and Köppen. (Ward has made no map of his regions.) The lettering and numbering of the provinces is the same as that appearing on these authors' maps showing climatic provinces over the whole world. Supan characterized his provinces as follows (**40**, pp. 55–60):

24=Northwest American coastal province—mild, equable, rainy climate.
1=Arctic province—no trees, and mean temperature of the warmest summer month never over 50° F.
23=Hudson (North Canadian) province—great extremes of temperature and little precipitation.

Herbertson's major natural regions are based on a unity of temperature, rainfall seasons, configuration, and vegetation; the most characteristic region in each type gives the name to that type wherever it may occur in the world. Hence, in Alaska, the characteristics of Herbertson's climatic provinces are indicated by the lettering on the map as follows (**13** and **14**):

2 a=West European.	(1=cold; 2=cool; a=western margin of continents; c=central lowlands; d=highland or plateau.)
1 a=Norway.	
1 c=Tundra.	
1 d=Yukon.	

The Köppen classification is made on a purely climatic basis, the letters indicating the following characteristics (**16**):

Cfb=Warm, temperate, rainy, climate; constantly moist; temperature of the warmest month less than 22° C. and more than four months greater than 10° C.; damp, temperate climate.
E 10=Tundra climate, snow.
Dfc=Sub Arctic climate; constantly moist; temperature of only one to four months more than 10° C.; coldest month more than −36° C.; cold climate with dry winters.

Ward does not delimit his climatic provinces in Alaska by exact boundaries, but he takes up his discussion using the following divisions (**41**, pp. 500–509):

I=Southeastern coast.
II=Alaska Peninsula and Aleutian Islands.
III=The Arctic Shore.
IV=The Interior.

Figure 1 shows the climatic provinces on which the seasonal weather discussion in this paper has been based, the numbers indicating the following names:

Ia=Pacific coast and islands (marine).
Ib=Pacific coast and islands (rain shadow).
II=Bering Sea coast and islands (semi-ice marine).
III=Arctic coast (ice marine).
IV=Interior (cold continental).

A study of all five classifications shows that in each case a differentiation has been made between the Pacific coast region, the interior, and the Arctic coast region, and in all but Ward's classification, the Bering Sea coast has been made a separate province. Figure 1 is distinctive in that:

(*a*) The Aleutian Islands and the Alaska Peninsula south of the Aleutian Range are included with the southeastern section of Alaska. This inclusion seemed to be justified by a study of temperatures and total and seasonal rainfall for the 12 stations included in the group. The boundary line was made the summit of the Aleutian Range.

(*b*) The boundary of the Arctic province has been made the summit of the Brooks Range, though of course no station data are available to indicate this, the assumption being merely that such a high elevation would be a very effective climatic barrier. The Arctic province is made to extend southward halfway across the Seward Peninsula, meeting the coast at the narrowest point of the Bering Strait, since this point probably marks a division between Arctic Ocean and Bering Sea influences on climate.

(*c*) Province Ib is indicated as a subdivision of the Pacific section because it depends on Pacific coast conditions for its temperature and rainfall, but being behind the coastal ranges, its temperature is not so equable nor its rainfall so great as on the immediate Pacific coast. Here again the boundary lines have been made the summit of ranges. The Alaska range protects this "rain shadow" province from the extremely cold winter temperatures of the Interior and the Chugach and Wrangell Mountains prevent its receiving the heavy rainfall and moderate temperatures of the coast.

The names of the provinces are intended to denote their geographic location, from which something of their climatic characteristics may be inferred. Further indication of the outstanding features of the climate of each province is made by the brief phrase in parentheses following the names. While it is hoped that from the names of the provinces themselves the general seasonal course of each of the climatic elements may be deduced, this section has been devoted to a rather full description of seasonal weather in each province. Since the reasons generally have been given before, this section aims merely

to describe seasonal conditions without any discussion of causes.

Figures 2 to 6 show graphically the monthly weather conditions for each of the provinces. The data from which these graphs were drawn were obtained by averaging the figures of all the stations in each province.

PACIFIC COAST AND ISLANDS PROVINCE (MARINE)

As the parenthetical characterization implies, this province is marked by ample rainfall with a fall and winter maximum, and by equable temperatures throughout the year.

This region, judging from a study of thermometer readings, should be the most pleasant in Alaska during the winter season. Mean temperatures for December, January, and February are but slightly below freezing, while average maximum temperatures for these months range around 45° and minimums are well above zero. Extremely low temperatures are never encountered here and ranges are too moderate to cause any discomfort on that score.

But temperature is not the only factor to be considered in determining a pleasing winter climate. The number of clear and cloudy days, frequency of fogs, amount of precipitation, and velocity and direction of winds all combine with temperature to make weather either agreeable or disagreeable as the case may be. That their combination during the winter is distinctly detrimental to the perfection of Pacific coast winter weather is apparent from what Henry Gannett says of the region at this season (**10**, p. 186):

> Take the well-known climate of San Francisco, with its dampness, fog, and cold sea winds; reduce the temperature 15° to 18° and increase the dampness and fog in proportion, and you have a fair idea of the climate of the Alaska Pacific coast.

As in any marine type of climate, cloudiness, precipitation, and fog, with accompanying lack of sunshine, are dominant features of the winter season in this section of Alaska. Only 6 to 10 hours of possible sunshine a day during the winter season is allotted to a region situated between 53° and 63° north latitude, but this section of Alaska with only an average of 35 clear days from October to February, inclusive, gets but little more than one-fifth of its allotted sunshine. Juneau receives an average of but 295 hours of sunshine during the winter, while the possible amount for its latitude is about 1,200 hours. The most northerly parts of this province with as few as five hours of possible sunshine on the shortest days would, of course, receive much fewer actual hours of sunshine than Juneau, but no records are available to show this.

Over the whole province during the winter season the monthly average of cloudy days is 20 and of clear days is 7, the remainder of the month being classed as partly cloudy. Juneau has an average cloudiness of about eight-tenths during the winter.

Though records of foggy days are lacking except for Juneau, and here they seem to be quite infrequent, Alaskan literature is filled with references to fogs. Furthermore, the contrast between the chilly air over the cold land or Bering Sea in fall and winter and the warmer, moisture-laden winds off the Pacific would certainly lead one to expect an abundance of fog. Indeed, there are stories that ships, attempting to reach ports on the Aleutian or Pribilof Islands sometimes miss the islands altogether because of fog and are forced to sail about for several days hunting for their destinations. The raw chilliness of frequent fogs, then, may be added to the general unpleasantness of the winter conditions along the Pacific coast.

In this province winter is a season of heavy precipitation, much of it coming in the form of rain at the recording stations, though it is probably mainly snow on the higher elevations. In the matter of precipitation and temperature, the station records may well be misleading for all the stations are quite near sea level, and presumably precipitation is greater and temperature less on the adjacent mountain sides. Substantiating this contention are the innumerable glaciers with which the whole of southeastern Alaska abounds, many of them of such size that they even reach the sea in spite of quite high summer temperatures.

About two-thirds of the days have precipitation amounting to at least 0.01 inch and still other days have traces. From what one hears of the type of rainfall in this section of Alaska, a "rainy day" means a steady, continuous drizzle for hours, punctuated with occasional periods of heavier downpours. Because rains are of this drizzling type, even though they last all day the maximum amounts in 24 hours generally do not average excessively high (only about 2 or 3 inches). A few instances of over 10 inches have been recorded, however, and 4 or 5 inches in a day occurs usually in each of the winter months at Cordova, Latouche, and Yakutat, though the averages for 24-hour maximums are only about 2 or 2½ inches.

Winter winds are strong, maximum velocities well over 30 miles per hour occurring at Juneau in all winter months. The prevailing direction is easterly—northeast, east, or southeast—for most of the stations during the winter. This direction is determined by the winter pressure distribution or by local topography, the whole province being a region of high relief. These winds blow from a cold region to a warmer one, though they are somewhat heated adiabatically in their descent from the eastward mountain ranges; being land winds, clear as well as cold weather accompanies them. On the other hand, the general cyclonic movement is on-shore, bringing moisture and accompanying clouds, fog, and precipitation to the coast. In this province, therefore, it seems that winter winds are disagreeable whichever way they blow, for they bring either coldness or dampness, or both (when warm ocean winds ride over cold land winds).

Spring is a transitional season marked by lengthening days, rising temperatures, variable winds, and decreasing rainfall.

Then comes summer time, in this part of Alaska said to be ideal. It is cool and clear, with long hours of daylight, and rainfall reaches its yearly minimum. June and July average under 5 inches and August between 5 and 10 inches. This is the tourist season, the mountain scenery and pleasant, invigorating climate attracting them, as do also those tangible results of climatic conditions, the scenic wonders provided by the great glaciers and the deep coniferous forests.

Summer shortly gives way to fall. September, October, and November bring the heaviest precipitation of the whole year, the days get shorter and shorter as the autumn wears on, fog, clouds, and drizzle set in with occasional snow flurries, mean temperatures gradually decrease, their decrease being slow and retarded, as was their increase, by the adjacent Pacific waters. By December the disagreeable winter season is well under way again.

PACIFIC COAST AND ISLANDS PROVINCE (RAIN SHADOW)

Between the immediate coast ranges and the crest of the high Alaska Range is a valley running from Cook Inlet to the Wrangell Mountains. While close to the Pacific Ocean the coast ranges keep out much of the ameliorating influence of the warm ocean waters and also most of the moisture-bearing winds. This region, while depending mainly upon Pacific coast influences for its climatic conditions, yet has those conditions so modified by the intervening mountain ranges that it has been made a separate province, the Alaska Range being a climatic barrier which prevents its inclusion in the interior province.

Winter temperatures are more severe than those of the coast province, for besides being shut off from tempering ocean winds, the lowness of the region, surrounded by mountain walls, causes the cold air to settle and find difficulty in draining away. The high Alaska Range, however, protects this region from the extreme cold which develops in the interior, only rarely allowing the cold winds to "spill over" into the valley, though sea-level pressure gradients would normally cause such winds to be the prevailing ones.

The number of cloudy days in winter averages about five or six a month less than on the Pacific coast, clear days being correspondingly more frequent. This region, therefore, though more northerly than the coast, probably receives as much and perhaps more sunshine than the coast because of its greater number of clear days. The lack of cloud cover is undoubtedly a factor in the lower temperatures of winter here than on the coast, for clearer skies permit greater nocturnal radiation.

A still greater decrease from coastal averages is noted in the number of rainy days in this province, there being only about one-third as many such days here as on the coast. This is, of course, due to the fact that the winds are chilled as they cross the coast ranges, thereby losing so much moisture that little is left to be precipitated in this rain-shadow region, and, furthermore, the winds are descending, and therefore warming and drying winds, as they enter this lowland.

Winter precipitation is low, averaging only a little over an inch a month. It is the precipitation factor which mainly distinguishes the region from the Pacific coast province, for besides the very much lower yearly total (less than one-sixth as much), the seasonal distribution is somewhat of the continental type. The rain-shadow province has an August and September maximum of precipitation, whereas the coast of which it is essentially a part has a September, October, and November maximum.

Spring is the least cloudy and least rainy season of the year. The winds in spring come from an ocean at its coldest temperature and so bring in the least amount of moisture, which becomes increasingly less by the time it reaches the rain-shadow region. The land is too cold to bring about convectional rains. Thus it is evident that the action of neither the marine influences which bring fall and winter precipitation nor the continental influences which bring summer rains, is vigorous enough in the spring to cause much precipitation. Hence, this is the driest season of the year.

The June, July, and August mean temperatures are practically the same as those on the Pacific coast, but the absolute ranges average between 5° and 10° higher, the maximum and minimum extremes both being somewhat greater in the rain-shadow region. The fact that the mean temperatures are slightly higher in summer in this province than on the immediate coast is probably due to its being protected by the coast ranges from the chilly ocean winds and also to its receiving more insolation, because of less cloudiness, than the coast. In spite of somewhat higher temperature in the three summer months in the rain-shadow province, the growing season averages only 109 days, while that of the coast averages 141 days. Frost days last, on the average, about 8 days longer in the spring and begin 24 days earlier in the fall in the rain-shadow province, illustrating the fact that protection from marine influences allows more rapid heating of the land in spring and more rapid cooling in the fall, the warm Pacific Ocean, with is attendant dense cloud cover, being especially effective in retarding the approach of cold weather.

Rainfall increases month by month from May to September. It seems to be a combination of convectional showers in the hottest months and a chilling of damp winds in the colder month of September. The September maximum, however, only averages 2.82 inches while in the same month the coast is receiving almost 11 inches.

Fall brings a rapid decrease in mean temperature, a 10° drop from the summer level of about 55° occurring between August and September, a similar drop from September to October, and one of 16° from October to November. This is the season of greatest number of cloudy days, these days continuing to be numerous though the rainfall decreases considerably.

It will be noted that this province has features of both continental and marine climates. It has a fairly low annual range of temperature and an early fall maximum of precipitation, both of which characteristics are marine; on the other hand it has greater extremes of temperature than the coast, and its summer precipitation is more than that of late fall and winter, which shows continental influences. Furthermore, its distinctly low total of precipitation precludes its climate being thought of as essentially marine. However, the fact that this rain-shadow region has a comparatively low annual range of temperature and an early fall maximum of precipitation indicates that it is dependent on Pacific coast conditions for its climate and it is therefore made a subdivision of that province.

BERING SEA COAST AND ISLANDS PROVINCE (SEMI-ICE MARINE)

Much of this province is a level, deltaic or coastal plain area where physiographic and climatic conditions favor a tundra formation. Trees grow only along the stream courses where drainage is better (3, pp. 98 and 99). The hummocky, moss-covered, ground never thaws to any great depth and is therefore always undrained and swampy, often with water standing between the hummocks in the warm season. It has been found that clearing off the tundra vegetation allows the ground to thaw sufficiently to make agriculture practical, but of course, this has not been undertaken on any vast scale (9).

Being farther north and also bordered by a colder sea, winter comes earlier and attains greater severity here than on the Pacific coast, the mean temperatures averaging below 10° F. during December, January, and February, while absolute minimum temperatures average well below zero from December to March.

The maximum wind velocities for Nome are always higher than for Juneau, as would be expected, for Juneau is protected by high mountains while Nome and all the Bering Sea coast area is subject to high winds sweeping across the flat surfaces of the ocean or the tundra. There are not even trees to break the winds as there are in the interior, and with a prevailing northerly direction during

the winter importing cold air from the polar ice cap, the importance of wind as one of the most disagreeable elements of the winter climate is evident.

Winter precipitation is light and comes practically all in the form of snow. An average of about 35 inches of snow falls from December to February, but the strong winds sweep many places clean and leave the snow piled in drifts where any protection is afforded. March brings a somewhat heavier snowfall than any of the three colder months, for in all this Arctic world the most severely cold weather is clear and it is the warmer springtime that brings clouds, snows, and rains.

Summer time shows a still higher percentage of cloudy days than spring, and has the maximum rainfall. In spite of a marine location, the Bering Sea coast has a continental seasonal rainfall distribution, apparently for two reasons. In the first place, the sea freezes over much of its area during the winter and this ice surface tends to take on land characteristics, which puts the Bering Sea coast, as it were, within a polar continent with no open seas close at hand from which moisture for winter precipitation could be brought; in the second place, the very low temperatures prevent the winds from gathering much moisture from open seas, "leads," or the ice itself, even when it is available. But the warmer days of summer, breaking up the ice and heating the land, cause convectional showers from the increased available moisture in the air and consequently the Bering Sea coast has a continental summer maximum of precipitation.

Maximum temperatures of over 80° may occur in June, July, and August, as may also minimums below freezing. George Byron Gordon, writing of a trip down the Kuskokwim River, says that the July sun "though not hot, had sufficient power to inflict a burn" (**11**, p. 47). He encountered only two thunderstorms during the whole summer's trip (1907), but apparently felt it to be rather unusual.

From August 10 on it begins to grow colder (**11**, pp. 99 and 100), but the figures show the greatest drop in mean temperature to be between September and October. September, Gordon says, is a month of heavy fog along the coast, as would be expected, for the land is at that time more chilled than the sea. By the end of September the sea has begun to freeze around Nome (**11**, p. 163), and winter is setting in once more.

While having a marine location, the fact that the Bering Sea is frozen during so much of the year modifies greatly the marine features of the climate. Hence, the name "Semi-ice Marine." The ice cover allows temperatures to go much lower than would be the case were the sea unfrozen; it provides much less moisture to the air and hence less precipitation to the land than open water would; it retards the coming of spring even more than ordinary large water bodies would, for so much of the sun's heat is needed to melt the ice before actual heating of the water can begin; it causes a summer maximum of precipitation by providing little moisture from its frozen surface and by chilling the air to such an extent that it can include very little vapor. Chiefly in these four ways does the ice cover modify the marine features of the Bering Sea coast climate, making it verge on the continental type.

ARCTIC COAST PROVINCE (ICE—MARINE)

> In the main the country traversed (the Arctic coast of Alaska) is as dreary and naked as I suppose can be found on earth, and cursed with as bitter a climate; yet it is not without scenes of great beauty and even sublimity, and its winter aspects have often an almost indescribable charm; a radiance of light, a delicate luster of azure and pink, that turns jagged ice and wind-swept snow into marble and alabaster and crystal. . . .

So writes Hudson Stuck, archdeacon of the Yukon and the Arctic, describing a winter journey he made along the Arctic coast (**25**, p. ix).

Winter conditions may be said to last the year round in this province, the only seasonal differences being a variation in intensity. Every month may bring snow and freezing temperatures, and from October to May temperatures below zero occur. At Barrow at least a trace of snow is recorded in each summer month every year for which there is a record. Candle, the only other station in the province and almost 400 miles farther south than Barrow, is generally free of snow in June, July, and August; but this situation can not be depended upon, for one year out of five is likely to bring at least a trace of snow in any of these months.

Though snow may fall throughout the year, it does not reach any appreciable depth, averaging only about 30 inches annually. Due to the very high winds, much of the land is blown free of snow, what little there is being piled in drifts in sheltered places. For protection against these high winds and the cold made more bitter by them, most of the native buildings are put partially underground. Doctor Stuck most vividly describes winter stormy weather on the Arctic coast such as he experienced while staying at the little settlement of Point Hope, located on a sand spit jutting into the Arctic Ocean about 250 miles west of Barrow (**25**, p. 106):

> The country between these elevations (Cape Thomson and Cape Lisburne) seems to form a natural chute for the northeast blizzards that prevail during the winter, and lying thus at the mouth of the chute, the barren sand spit is swept by gales of a prolonged ferocity that we who knew only the forested interior of Alaska had no experience to match. From the 1st to the 8th of January, 1918, without, I think, a moment's cessation, day or night, a raging blast prevailed from that quarter, with the thermometer at 15° to 30° below zero F., and that was only one of many storms during our six or seven weeks at the place. At what rate the wind blew I could not guess. There had been several installations of an anemometer at the mission, and the interior mechanism yet remained, but the vane had been blown off every time. If the reader will add to these violent, persistent winds, first the driving snow and sand with which they are charged, then the cold that accompanies them, and then the darkness, at a season when the sun does not rise above the horizon at all, he will understand that any continuous travel against them is out of the question, and that even to be outdoors upon necessary occasions while they rage is fraught with discomfort and difficulty, not to say danger. Storms we have in the interior, in certain regions, and especially in certain reaches of rivers, high winds that blow for many hours in one direction, but nothing that I have known in 10 years of winter travel comparable to these awful Arctic blizzards.[5]

But storms, wind, and low temperatures are not continuous—cyclonic variations in weather occur and are welcomed even as they are welcomed in more temperate climates. Temperatures may rise from −40° to −10° and seem, by contrast, quite comfortable, especially if accompanied by a calm. "Thirty-seven degrees below zero is not a bad temperature for traveling if it be calm" (**25**, p. 286).

Calms, however, give rise to another disagreeable feature of Arctic winters—fog. Doctor Stuck says: "This whole coast is an exceedingly dangerous one, beset by fog when it is calm and lashed by gales almost whenever it is clear" (**25**, p. 166). Before the extreme and dry cold of winter becomes firmly established, the air contains more or less moisture which causes frequent fogs in November and December when temperatures go low enough to condense the moisture. Cyclonic storms

[5] Doctor Stuck made this trip in 1917–18 which is the worst winter on record in Alaska (**8**), so that perhaps the awfulness of his picture of Arctic winter weather may be modified somewhat in normal years.

cause the same conditions even in February for Doctor Stuck mentions the following occurrence during his February journey from Point Hope to Point Barrow (**25**, p. 203):

> A rapid fall of temperature to 30° below zero had brought the usual accompaniment of fog. The moisture with which the air had been loaded in the late snowstorm and comparative high temperatures, was now condensing and would presently be deposited as hoar frost, then the air would be clear.

March and April, when the cold has relaxed somewhat, bring frequent fogs. Wilkins and Stefansson both experienced and made note of these spring fogs. Wilkins writes (**42**, p. 534):

> But spring conditions had already set in at Barrow. The fog which had hitherto cloaked only the tundra was creeping out over the Arctic Sea ice. * * * Hoping that we might have at least one clear day, we waited for a period of two weeks; but the fog did not lift.

Stefansson, writing of conditions on the ice near Banks Island on April 10, says (**23**, p. 296):

> It was exceedingly cold and clouds of steam were seen rising here and there. These worried us a bit, for we thought they might be from opening leads, danger signals that the break up of our ice had commenced. But there was about an even chance they might be rising merely because 6-inch ice is so warm from the water underneath that it throws off clouds of vapor if the air is at a low temperature.

Climatologically speaking, ice conditions along the Arctic coast are of great importance because of their modification of the marine features of the elements of temperature and moisture. The effects of the ice cover are the same as those described for the Bering Sea coast, but are of longer duration. The "fast ice" breaks up perhaps only for six weeks in the summer, allowing the passage of ships along the coast. The United States revenue cutter makes a yearly trip to Barrow and trading vessels go along the coast as far as Herschel Island near the mouth of the Mackenzie. The ice begins to break up in May and June, starting from a "flaw" a mile or so offshore between the "fast ice" and the "pack ice" (**22**, p. 92). August is probably the best month for water travel though in some years the ice may never break sufficiently to let boats through. By October the ice cover is forming again from the shore, reaching its greatest extent about December, but continuing to grow in thickness the whole winter and spring up to May (**12**, p. 109).

Summer comes quickly, brought on by the rapid change in length of days. Then the coast reveals itself as a tundra area, flower and moss covered and very marshy, the still frozen ground below preventing proper drainage. Temperatures rise until a mean of about 45° is attained in July and August and maximums between 70° and 80° are recorded at Barrow and even over 80° at Candle. But winds off the Arctic ice still bring minimums below freezing.

After the darkness and semidarkness of winter one would expect inhabitants of these northern latitudes to look forward with joy to the long hours of daylight in the summer time. That this is not strictly the case is brought out in the following quotation from Doctor Stuck (**25**, p. 210):

> The sun is absent in the winter for two full months—from the 21st of November to the 21st of January, which, of course, does not mean that daylight is totally absent, as some seem to think, but only that the sun is not seen. Conversely, in summer he does not leave the sky for two full months and there is daylight all night for almost two months more. To most residents in these latitudes I think the perpetual sunshine is more trying than the darkness, for there are always three or four hours' daylight on the darkest day, but there is no escape from the glare of the sun, no kindly decent gloom for the hours of repose.

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July and August bring the greatest amount of precipitation, these being the only two months of the year with over an inch. The delay of maximum temperatures and of heaviest rainfall until July and August, several weeks after the highest sun, results from the use of all the heat in early summer to melt and evaporate the ice and snow cover, rather than to warm up the land. By September days are getting shorter and by October the heat from the sun is easily overcome by nocturnal radiation and cold sets in again. The shores become icebound, precipitation comes in the form of snow and remains, the people don their fur clothes once more, and prepare to spend most of their days in their underground homes. From November till the next May no temperature above freezing can be expected at Barrow, and from December until April even the means are well below zero.

INTERIOR PROVINCE (COLD CONTINENTAL)

This is the province having the greatest diurnal and annual temperature contrasts in all Alaska, which, with its summer maximum of precipitation, characterizes it as "continental."

Winter, with its long hours of darkness every day, gets very cold—colder than anything along the Arctic coast, where tempering marine influences make themselves felt in spite of the ice sheet. Temperatures as low as −70° have been recorded and the winter mean temperatures are lower than those of the Arctic coast, though the maximums are higher. The lowest temperatures occur when the weather is clear, for clear skies foster the utmost radiation. Wind velocity in the interior does not compare with that of the Arctic coast, the sweep of the winds being broken by the varied relief and the forest cover, and, indeed, even being prevented from reaching a valley bottom because the valleys are often filled with very dense, cold air; furthermore, the air contains little moisture; therefore the low temperatures can be supported more easily here than the somewhat higher minimums of the Arctic coast, which are accompanied by strong, damp, northeast winds off the ice. Moreover, the variety of weather brought by cyclonic action does not usually allow the coldest weather to last for a very long time.[6]

Cloudy days in the interior province in winter number slightly over 10 a month, being somewhat more numerous than on the Arctic coast but by no means so numerous as in the other two coast provinces. Winter precipitation in this province is chiefly snow, the average for the year being about 50 inches, 20 inches more than in the Arctic coast province and about that received in Massachusetts. Each of the months from October through March receives about the same amount of snowfall, the average being 8 inches a month.

Rapid lengthening of the days brings a quite sudden shift from winter to spring for the long hours of sunshine exercise a thawing action even while air temperatures are low. As soon as the snow is melted and evaporated from exposed places, temperatures rise quickly, the greatest differences being noticeable between the means of March and April. Within a week flowers and green leaves appear on plants and trees, geese and ducks arrive, and other birds soon follow (**22**, p. 113). Then, too, come mosquitoes—"far more serious in the minds of all who know than winter darkness, extreme cold, or violent winds," says Stefansson (**23**, p. 245).

[6] An instance of a long period of cold weather was that experienced at Eagle in December, 1917. The temperature never rose above −25° and the mean for the month was −46°; the lowest previous mean for the same month, in a more or less complete record covering 30 years, was −23° (**8**).

Summer is a more significant season in this Province than in the other Alaskan Provinces for it offers a greater contrast to winter conditions. In the other Provinces the contrast between summer and winter is very materially reduced by marine and ice influences, so much so along the Arctic and Bering coasts that summer can scarcely be said to come at all. Such conditions would obtain in the interior Province were it not for the smaller amount of snow or ice cover and the greater ease with which land bodies absorb heat and therefore the quite warm temperatures attained in the interior in the summer are the more conspicuous. The midsummer means are higher than those experienced in Massachusetts in May and October and maximum temperatures from May to August may be over 80° and in July even over 90°.

The rapid heating of the Yukon country quickly brings temperatures high enough for planting. The growing season lasts from the 1st of June until the end of August, allowing sufficient time for the ripening of native and cultivated berries, vegetables, and even some grains, though weather conditions are usually too precarious to make profitable any attempt to grow wheat.

Summer is also the season of maximum precipitation, which fact is favorable for cultivation. Though this precipitation is not high, being but little over an inch a month in the summer and only about 11 inches for the year, the low rate of evaporation when temperatures are low makes this amount sufficient for agricultural purposes as well as for the growth of quite abundant forests of birch, willow, alder, and spruce.

The shortening days of August and September bring in cold weather again, and greatest drop in mean temperatures occurring between September and October. The coming of the cold is hastened in the interior for there is no large water body to retain the warmth for a long period of time. Late in October the rivers are all closed for water travel but November finds them frozen solid enough to make smooth going, rapid ice travel possible (**25**, p. 4). The snow and ice covers increase the possibility of extremely low temperatures and so winter again grips the land.

In Alaska, as elsewhere, climate is really the basic element of the environment. But in polar regions more than in other parts of the world, the climate is so extreme that it demands a more perfect adjustment on the part of man, animals, and vegetation than a more temperate climate requires. In order to live at all every living thing must provide itself with adequate protection against the low temperatures, the high winds, and the scant precipitation. Climate is in no way a passive factor which matters little one way or another—it is a very active, paramount consideration in all phases of every day living.

Thus one finds Doctor Stuck, primarily interested in the human affairs of his large archdeaconry, continually hampered or favored in the accomplishment of his work by climatic conditions. His books have references to the weather on practically every page and the same is true of most Alaskan books. Alaskan weather is not something that may be taken for granted, it demands and receives notice.

In this section, as in Section II, the contrast between the Pacific coast region of Alaska and the rest of it has been brought out time and time again. The Pacific coast region has a really temperate climate resembling that of the northwestern coast of the United States, whereas all the rest of Alaska has a distinctly cold type of climate the year round, modified mainly by proximity to, or distance from, the surrounding oceans. Thus, in a broad way, this paper has been concerned mainly with describing the extremes of a polar climate in contrast to the moderateness of a temperate marine climate, the distinctive features of each being made more prominent because of the sharp differences between them.

Only references of which actual mention has been made in this paper, or which were studied in preparation of it, have been included in this list. If further bibliography is desired, reference 2 provides a very exhaustive one.

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GULF STREAM STUDIES: GENERAL METEOROLOGICAL PROJECT

By CHARLES F. BROOKS

[Clark University, Worcester, Mass., March 15, 1930]

THE GULF STREAM AND THE WEATHER

It is the common impression along the Atlantic seaboard that the Gulf Stream has important effects on the weather. When the wind blows on-shore from an easterly to southerly direction for some time, balmy air, of soft springlike quality, usually reaches the shores. A number of such occurrences in a season suggest that the Gulf Stream is nearer or warmer than usual.

But there is another side to the matter. Winds are prevailingly offshore in the colder months, so the character of these land winds will dominate the season. Winds from the west or northwest are generally cool and dry on the Atlantic slope, and the stronger they are the more pronounced are these characteristics. More northerly winds now and then attend much snowfall.

Now, how can the Gulf Stream have anything to do with these winds blowing toward it? Through storms, is the answer. We know that, whatever the wind direction and velocity, they are in accordance with the particular distribution of pressure at the time. To provide a maximum of westerly to northerly winds, therefore, we should have a frequent occurrence of low-pressure areas centered off the coast (1). And this will occur most readily when conditions most favor storms there. It is generally agreed that the sources of energy for oceanic storms are abundant heat energy latent in water vapor and marked contrasts in temperature. The Gulf Stream supplies much water vapor and its warmth is in great contrast to the coolness of the neighboring continent. Therefore, the Gulf Stream favors the very winds and snows that make our eastern climates cooler than the averages for their latitudes.

THE GULF STREAM

High temperature, speed, magnitude, and location make the Gulf Stream the best known of all ocean currents. The habitability of northwestern Europe is commonly ascribed to the high temperatures of the Gulf Stream, though this current is only part of the warm flow that ameliorates European climate (2). The climatic importance of the Gulf Stream and the other warm waters of the western Atlantic has still to be fully appreciated. It is generally recognized, however, that these warm seas are the sources of rainfall for eastern North America and the progenitors of storms.

The speed of the current, 1 to 4 knots, is a notable aid or hindrance to navigation, though less so nowadays than in the period of sailing ships. The commerce of the busiest ocean feels the movement, the warmth, and the storms of the Gulf Stream. Even aerial navigation is disturbed by the bumpy air over it. The clear blue waters of this tropical current are sharply contrasted with the colder green waters on its left, while the Gulf Weed (Sargassum) and tropical fauna, including the picturesque Portuguese man-of-war (Physalia spec.), add their touch of life.

The breadth of the Stream and its unseen depth make even the mightiest rivers seem tiny. A ship steaming across even its narrowest section, in the Straits of Florida, where the Gulf Stream occupies practically the entire width of the Straits, loses sight of land long before the other shore appears. The crossing is a matter of hours, and the sideways drifting of the vessel in the current, a distance reckoned in miles, sometimes tens of miles. In the Straits the current extends to maximum depths of half a mile to a mile.

The general flow arises from the difference in level between the warmed and expanded tropical waters and the denser colder waters of higher latitudes (3), while the particular concentration of the current into a fairly swift river 40 to 60 miles wide and half a mile to a mile or more deep is due largely to the trade winds and the configuration of the West Indies and eastern coast of North America. After leaving the confining Straits of Florida the Gulf Stream spreads, becoming less deep and prominently streaked with cooler bands. It maintains, however, a "cold wall" on its left. (See fig. 1.) The greater density of the much colder waters causes lower pressures level for level west and north of this cold wall than those of the warm Gulf Stream, which is clearly to be seen on Jacobsen's topographic maps, for the surface, 200, 500, and 800 meters depth (4). This pressure gradient and the deflective effect of the earth's rotation continue to drive the waters rapidly (5), northeastward then eastward to the Grand Banks, where the Gulf Stream becomes entangled with the Labrador Current (6). (See map, fig. 2.) Beyond the Grand Banks the contrasts are so diminished that the current is considerably slower. The surface waters drift generally eastward before the prevailing westerly winds (7). This is the Gulf Stream in brief, a much talked about but still relatively little studied river in the sea.

The United States Coast and Geodetic Survey, beginning in Maury's time, has sent many expeditions to study the Gulf Stream, the results up to 1890 being presented by John E. Pillsbury in an extensive appendix (No. 10) to the United States Coast and Geodetic Survey report for 1890 (8). Nor did its work stop here; its investigations have continued from time to time till the present, some of the latest ocean data having been gathered on the S. S. *Lydonia* early in 1929. The United States Bureau of Fisheries has also been prominent in Gulf Stream studies (9). Some recent observations have been made by P. Idrac on the yacht *Jamaica* (10). Present knowledge of this great ocean current is admirably summarized from the physical oceanographic standpoint, by H. A. Marmer, of the United States Coast and Geodetic Survey, in a recent paper in the Geographical Review (11), and by Georg Wüst, general secretary, gesellschaft für Erdkunde, Berlin (12). From a meteorological angle, general statements by C. F. Brooks, and H. V. Miller appeared last year in the Bulletin of the American Meteorological Society (13), and by C. F. Brooks in the MONTHLY WEATHER REVIEW in 1918 (14). All these papers contain references to earlier ones.

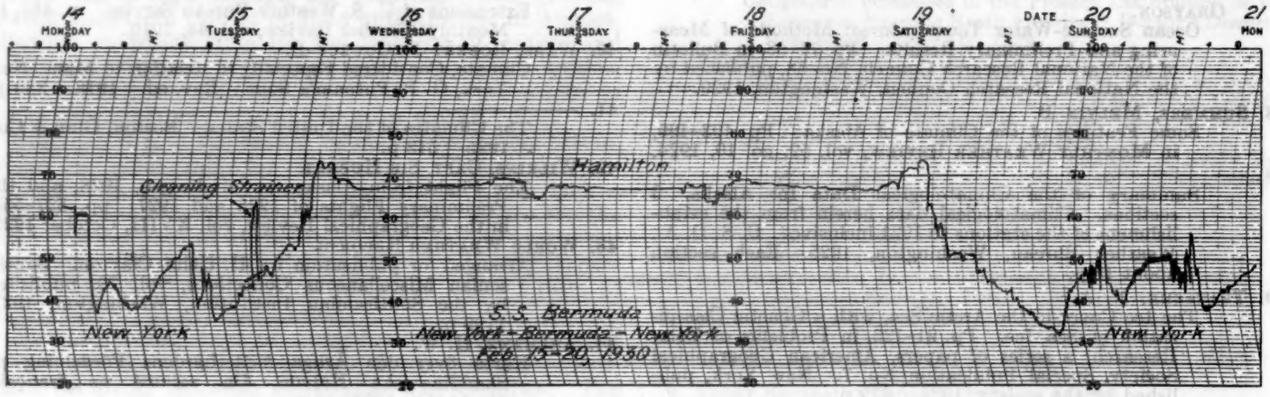

FIGURE 1.—Profile of sea temperature between New York and Bermuda February 15–20, 1930, made by sea-water thermograph on motor ship *Bermuda* of the Furness-Bermuda Line

There was a notable rise of sea temperature from 35° at New York to 53° at the north side of the cold wall, and then jumped upward 8°, then 12°, to 73° as the Gulf Stream was entered. The really warm portion of the Gulf Stream was soon passed, and the Stream was left altogether about five hours after it was entered. The temperature of the Antilles Current between it and Bermuda ranged from 67° to 68°. On the return trip the Antilles Current was slightly cooler, the maximum temperature of the Gulf Stream, however, slightly higher, nearly 74°. Also, the fall at the cold wall was greater, amounting to 22°. The total fall from the warmest of the Gulf Stream to the coldest at New York, 32.5°, was over 41°.

On the outbound trip there was a northwesterly to northerly gale with snow. At 2 and 4 a. m. the 16th, while the thermograph recorded 73°, the bucket observations showed but 59° and 65°, so great was the cooling by the cold gale. There could be no clearer demonstration of the difficulty of obtaining satisfactory sea temperature records with a canvas bucket in severe weather.

The ship left New York (Fairway buoy, off Ambrose Lightvessel) at 12:52 p. m., February 15th, was at 35° 49′ N., 68° 32′ W., at noon the 16th, and arrived at Bermuda (Mills breaker buoy) at 7:11 a. m. the 17th. Returning, it left Bermuda at 10 a. m. February 18th, was at 37° 00′ N., 70° 07′ W., at noon February 19th, and arrived in New York 5:38 a. m. the 20th. The ship's speed on this voyage was about 16 knots. The tidal ups and downs of temperature before noon on the 15th and after 9 a. m. the 20th are temperature changes while the ship was at dock.

This record was obtained through the courtesy of Mr. Benjamin Parry, in charge of the marine work, New York office, United States Weather Bureau.

[Since this map was prepared, it has been learned that one of the Canadian ships covers the route from Bermuda to Trinidad, thus providing a temperature record all the way across the Equatorial Current as it enters the Caribbean Sea.—*Author*.]

THE GENERAL METEOROLOGICAL PROJECT FOR INVESTIGATING THE GULF STREAM

In the paper on "Ocean Temperatures in Long-Range Forecasting" (14), 11 years ago, the writer indicated: (1) How the Gulf Stream as a warm body of water favored precipitation, storminess, and low pressure, thereby constituting an important factor in the climate of our eastern seaboard—in winter, for example, favoring

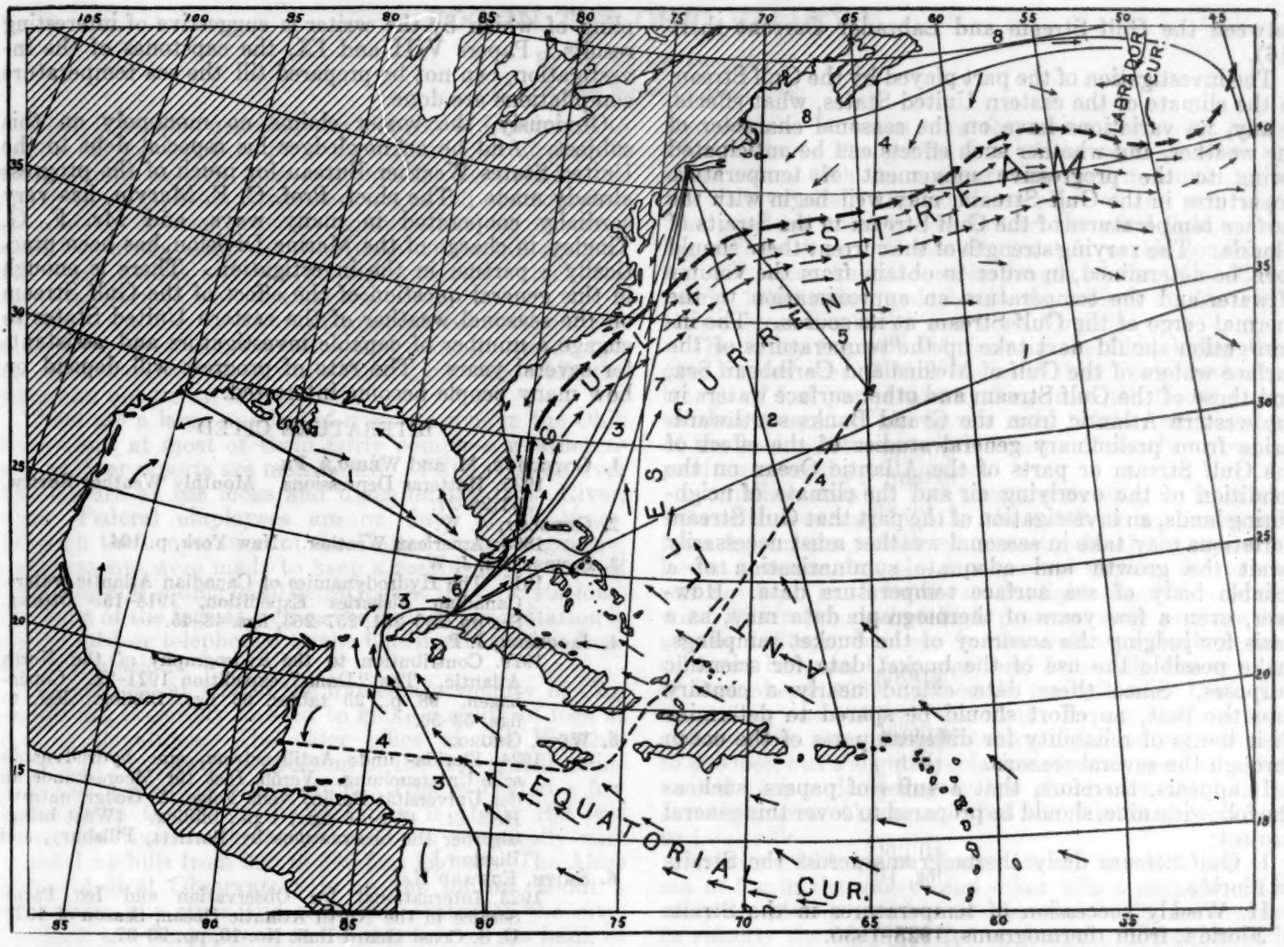

FIGURE 2.—The Gulf Stream (after Pillsbury (7), Smith (5), and United States Hydrographic Office, North Atlantic Pilot Chart, March, 1924, and steamship lines on which one or more sea-water thermographs are regularly crossing it): (1) French training ship *Jacques Cartier*, Le Havre to Gulf ports, with the first sea-water thermograph regularly crossing the Gulf Stream; (2) the Porto Rican Line steamship *Coamo*, instrument purchased by United States Weather Bureau (1926); (3) the Panama Pacific Line steamships *California*, *Virginia*, and (later) *Pennsylvania*, instruments purchased by Clark University (1926), the American Meteorological Society (1930) and (later) the Panama Pacific Line (1930); (4) on steamships *Canadian Forester* and *Canadian Fisher*, Montreal or Halifax to British Honduras, instruments purchased by Canadian Meteorological Service (1927); (5) the Furness-Bermuda Line motorship *Bermuda*, thermograph purchased by the Furness-Bermuda Line (1928); (6) Peninsular and Occidental steamship *Henry M. Flagler*, between Key West and Habana, instrument purchased by the American Meteorological Society (1928). The Munson Line (7) is purchasing a sea-water thermograph for steamship *Munargo*, on the route New York–Nassau–Habana–Miami–New York. The International Ice Patrol (8), operating from Boston and Halifax to the Grand Banks during the iceberg season, February or March to July, installed sea-water thermographs on its two ships, the *Mojave* and the *Modoc*, in 1927. That on the *Modoc*, however, was transferred to the *Marion*, in 1928, and later was destroyed by fire. The instrument on the *Mojave* is being removed temporarily for repairs. All these instruments are under the general charge of the French, Canadian, or United States Governments, the seven out of New York being under the care of Mr. Benjamin Parry, marine official, New York office, United States Weather Bureau. The records from the Canadian ships go to Dr. A. G. Huntsman, of Toronto University; those from the Panama Pacific liners and the Peninsular and Occidental Line to the writer; and the rest to the United States Weather Bureau, Washington. Photostat copies of thermograms from the *Jacques Cartier* are filed in the Hydrographic Office, U. S. Navy, Washington

colder and wetter weather than if the waters were not so warm; (2) how variations in Gulf Stream temperatures from year to year, even though amounting to no more than 2° or 3° F. on either side of the normal, are probably in part responsible for considerable seasonal variations in the character of our eastern seasons, and (3) how through movements of temperature departures in the Gulf Stream it should be possible to anticipate some of our seasonal weather abnormalities.

The then available data on Gulf Stream temperatures, obtained by inserting thermometers in samples of sea water drawn up from the surface in a small canvas bucket, proved to have inaccuracies considerably greater than the variations to be studied. An average error of 5° F. was found in the bucket data obtained on a number of steamships crossing the Gulf Stream in the open Atlantic in winter (15). The Gulf Stream is warmer than our past records have given it credit for being. The inaccuracies of the old method led to the now considerable installation of sea-water thermographs, which give both accurate and continuous records on several lines across the Gulf Stream. (Fig. 2.)

The surface temperature of the Gulf Stream averages 80° F. in the Straits of Florida, ranging from 73 to 77 in February or March to 85 or 86 in August in the left and right portions of the Stream at the western entrance to the Straits. Though the thermograph data for other portions of the Gulf Stream have not yet been reduced, an inspection of the records indicates that the temperatures of the Gulf Stream fall but slowly downstream to the northeast. This is owing to the speed of the stream and to the great mass of water involved, even though such a high temperature does not extend far below the surface. Pillsbury (8) and others (12) have estimated that the flow of water is about 90 billion tons an hour, roughly half of which is the warm upper 200 meters. Southeast of New York the Gulf Stream does not fall below 70° in its warmest portion at any time of the year, while in summer its temperature exceeds 80°. Near the Grand Banks the temperatures are 5° to 10° lower, though still so much above the coldness of the Labrador Current that a contrast of 22° F. has been observed between stem and stern of an ice patrol ship lying across the boundary

between the Gulf Stream and Labrador Current there (16).

The investigation of the part played by the Gulf Stream in the climate of the eastern United States, what effects, if any, its variations have on the seasonal character of the weather, and whether such effects can be anticipated owing to the progressive movement of temperature departures in the Gulf Stream, may well begin with the surface temperatures of the Gulf Stream in the Straits of Florida. The varying strength of the current there should then be determined, in order to obtain from the volume of water and the temperature an approximation to the thermal cargo of the Gulf Stream at its source. The investigation should next take up the temperatures of the surface waters of the Gulf of Mexico and Caribbean Sea, and those of the Gulf Stream and other surface waters in the western Atlantic from the Grand Banks southward. Aside from preliminary general studies of the effect of the Gulf Stream or parts of the Atlantic Ocean on the condition of the overlying air and the climate of neighboring lands, an investigation of the part that Gulf Stream variations may take in seasonal weather must necessarily await the growth and adequate summarization of a reliable body of sea surface temperature data. However, even a few years of thermograph data may, as a basis for judging the accuracy of the bucket samplings, make possible the use of the bucket data for scientific purposes. Since these data extend nearly a century into the past, no effort should be spared to determine their limits of reliability for different parts of the ocean through the several seasons.

It appears, therefore, that a series of papers, such as the following nine, should be prepared to cover this general project:

I. Gulf Stream daily thermograms across the Straits of Florida.

II. Weekly succession of temperatures in the Straits of Florida, from thermograms, 1928–1930.

III. Thermal cargoes of the Gulf Stream through the Straits of Florida.

IV. Gulf Stream surface temperatures across the Straits of Florida—car-ferry series, 1917–1921 and 1928–1930.

V. Methods of mapping and summarizing ocean surface temperature data, with special reference to the Straits of Florida.

VI. Gulf Stream, West Indian, and other southwestern North Atlantic sea surface temperatures from the earliest records to the present time.

VII. Flooding rains in the eastern United States and their relation to evaporation from the Caribbean Sea, Gulf of Mexico, Gulf Stream, and tropical North Atlantic, as indicated by their surface temperatures.

VIII. The Gulf Stream during and prior to certain abnormal seasons in the eastern United States.

IX. Can the known or anticipated thermal cargoes of the Gulf Stream be used in forecasting the weather of a fortnight, month, season, or year in the eastern United States?

The first two papers in this list will appear in early issues of this REVIEW. Numbers III, IV, and V have been given considerable study by the writer, and should appear within two or three years. Paper VI will represent a major job of compiling; it is now in progress for the region south of latitude 30° as a by-product of the revision of the West Indian portion of the North Atlantic Pilot Charts by the United States Weather Bureau. The relation of flooding rains in the eastern United States to the surface temperatures of the tropical waters on the south and southeast (VII) is an enticing subject, a sampling of which by the writer is suggestive of interesting results. Papers VIII and IX, the capstones of the investigation, can not be prepared till the sea temperature compilations are done.

Obviously, the writer claims no monopoly on this subject. And he acknowledges his especial debt to the United States Weather Bureau for much of the progress already made. The chief, Prof. C. F. Marvin, has very cordially cooperated in many ways, and Mr. F. G. Tingley, in charge of the Marine Division, has been practically a partner in the investigation. There is enough in this general question of the effect of the Gulf Stream on the seasonal weather of the eastern United States to engage a number of capable investigators and assistants for several years. The rate of progress will depend on how many people become interested.

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FOG IN THE OHIO VALLEY[1]

By W. C. DEVEREAUX

[U. S. Weather Bureau, Cincinnati, Ohio]

When it became necessary for the city of Cincinnati to decide on the location for a new municipal airport, it became more evident than ever that the fog data for the region along the Ohio River were not as full and complete as needed. It was generally known that fog occurred more frequently along the river than on the hilltops, but the exact excess and the conditions under which the river fogs formed were not known.

Before the day of the airplane the information was needed for river transportation and other purposes, but the river boat can tie up while the fog prevails, while the plane can not tie up to a cloud.

There are a large number of river stations in the Ohio Valley and at most of them fairly complete weather as well as river reports are maintained. Fifty of these river stations are at the locks and dams on the Ohio River, where Federal employees are on duty at all times. Through the cooperation of the United States engineers, arrangements were made to keep a record of the time of beginning and ending of all dense fogs at the river stations. The time of the fogs as well as the time of precipitation is telegraphed or telephoned to the Cincinnati station from the river stations.

The stations at and in the immediate vicinity of Cincinnati are favorably located to make a study of fogs at various elevations. The older office of the Weather Bureau in the downtown section of the city is still maintained as a point of observation. This is located a few blocks from the river, the elevation is about 100 feet above the river bank, and the site is practically surrounded by hills from 200 to 300 feet higher. The Abbe Meteorological Observatory is on the hilltop, about 4 miles from the river and near the center of the city. The lock and dam known as Fernbank is on the bank of the river about 10 miles below the Federal Building, but within the city limits, while Dam No. 36 is about an equal distance upstream from the Federal Building. All the other river stations are on the banks of the river, but some are located in open country, while others are partially surrounded by hills of various slopes and heights.

At the principal station of the Weather Bureau in Cincinnati dense fog has been recorded 461 times in the last 37 years or on an average of 12½ days per year. Of these fogs, 92 or 25 per cent have occured in October, about 15 per cent during each of the months from September to February, inclusive, and only a few during the summer months. Most of these fogs might be called general fogs to distinguish them from river or valley fogs.

From a year's record of the fogs at the river stations it is indicated that the valley fog will occur on 15 to 20 days during the year in addition to the days with general fog. However, occasionally the general fogs do not settle into the valleys, but rest only on the higher ground. The valley fog occurs more frequently during the summer than the winter months, just the reverse of the general fogs.

The true valley fog forms from one to three hours after midnight and burns up an hour or two after sunrise. The weather, of course, is usually clear above the fog. The fog usually forms near to or just to the south of the center of an area of high pressure. Rain falls within the previous 12 hours over the region just south of the Ohio Valley. The gentle flow of the cool air from the north mixes with the comparatively warm humid air in the valleys along the northern edge of the rain area. The gradient must be gentle and the wind light or the fog will not form. Under the most favorable conditions fog will form along the entire length of the Ohio River, nearly 1,000 miles, and also in the valleys of the tributaries across Kentucky and West Virginia.

The valley fog will also form in the Ohio Valley, but over limited areas, along the wind shift line of a shallow trough of low pressure extending from the Great Lakes southwestward. This occurs only when the overflow of the cool northwest wind is not sufficiently strong to produce general precipitation.

A shallow area of low pressure moving in from the west with a strong high to the north or northeast will form fog on the northeast or east side of the center of lowest pressure, but this is a general fog and frequently will not form in the valleys. A slight circulation of the wind within an area of high pressure may produce fog on the hilltops, but not in the valleys. Such a case occurred between Cincinnati and Louisville the evening of December 9, 1929. When the mail pilot left Louisville the ceiling was 600 feet, and at the airport at Cincinnati and the two river stations between the ceiling was 400 to 500 feet, but a slight circulation of wind over the region caused such a dense fog or low cloud over the hills in Kentucky near Cincinnati that the pilot had to return to Louisville.

From the hilltops at Cincinnati one can look across a sea of fog in the valley, and other hills 5 miles or more away are plainly visible. As the wind begins to increase in velocity the fog is packed against the side of the hills and into the pockets, refusing at first to rise over the hills; when the wind becomes sufficiently strong the fog streams over the hills as great rivers, always following fairly well-defined channels. In a distance of 2 miles from the Abbe Observatory toward the business section of the city and the Ohio River and along a fairly level street one will occasionally pass through three streams of very dense fog about one third mile broad. These rivers of fog follow quite definite courses.

Fogs are the greatest obstacle that the airplane has to overcome in the Ohio Valley. The valley fog interferes with the landing of the plane, but is not a serious obstacle to the take-off. The mail plane due at Louisville at 5 a. m. from Cleveland frequently has to wait at Cincinnati or elsewhere for the fog to disappear at Louisville, but the Chicago plane from Cincinnati leaves the local airport in a valley fog if other conditions are favorable.

Fogs can be forecast about the same as any other weather phase if information about the same is collected by telegraph. With our present method of reporting observations, fog is reported only when it occurs at the Weather Bureau station and at the time of observation. We have had reports of dense fogs at as many as 20 stations in the Ohio Valley when the Washington weather map did not show a single fog and only meager information was sent to the airway control stations at Chicago and Cleveland. The two latter stations make flight forecasts for planes going into and out of the Ohio Valley, and the district forecaster at Washington makes a flying weather forecast for zone 5, the Ohio Valley.

[1] Presented before American Meteorological Society, Des Moines, Iowa, Dec. 28, 1929.

AN UNUSUAL SNOWSTORM IN TEXAS

By EDWIN J. FOSCUE

A few days before Christmas, 1929, Texas was visited by a snowstorm of unusual severity, which paralyzed traffic in the central portion of the State. The quantity of snow that fell at certain places was much higher than the average for a region that far south (26 inches at Hillsboro in central Texas), and this factor made the storm one of unusual interest. Texas has a north and south extension of about 800 miles. In the "Panhandle" region heavy snows are quite common every winter, while along the Gulf coast and in the lower Rio Grande Valley area snow is practically unknown, and even in central Texas snows are rare. In this storm northeast Texas had no snow; even the extreme northern part of the "Panhandle" was without snow or with only a trace, while central and south Texas had very heavy snows.

Because of the unusual distribution of the snowfall during this storm as reported by the newspapers of the

FIGURE 1.

State, the writer became interested in determining the true state of conditions which might bring about such a freakish storm. Questionnaires were mailed out to the cooperative weather observers of the State, some 240 in number, asking for (1) minimum temperature, (2) rainfall in inches, (3) snowfall in inches, and (4) wind directions, for each of the four days of the storm from December 19 to December 22, together with total snowfall for the four days. Out of the 240 questionnaires mailed out, 180 were returned, and 171 of these had complete enough data as to be of value. Minimum temperature and snowfall were reported on almost completely; rainfall and wind directions less accurately. The data obtained from these questionnaires are shown in Table 1. (For 5 or 6 representative stations in each of the 7 sections into which the State is divided by the climatological service at Houston, Tex.). The distribution of the stations is shown in Figure 1, together with the path of the center of the storm during its four-day trip across the State.

PRESSURE

Pressure conditions over the United States for the four days of December 18, 19, 20, and 21, as shown on Figure 2 (reproduced from Government weather maps published in Washington on those dates), show a definite mixing of low and high pressure phenomena over Texas, which caused the heavy precipitation in the form of snow. On December 18 the high-pressure area of Montana (31 inches in the center) had a pronounced southward extending tongue which reached below the Rio Grande. On that same date an intense low-pressure area (29.6 inches in the center) dominated the Gulf Coast States, bringing in large quantities of warm moist air from the Gulf of Mexico. This tongue of cold, dry air accompanying the HIGH slipped into west Texas from the north and then turned eastward, moving over to the Atlantic coast. On December 20 and 21 the HIGH occupied the place that was occupied by the LOW on the 18th. The moisture was already there, ready for a wind cool enough to cause condensation. The wind accompanying the HIGH was not only cool enough to cause condensation, but actually cool enough to cause the moisture to be frozen and to be precipitated in the form of snow. While heavy snows sometimes occur in the south, due to the mixing of cold air with the warm, moist air from the Gulf, from 4 to 8 inches is usually a very heavy fall for a 24-hour period.[1] Actual Government records for Hillsboro, Tex., report a 26-inch fall for a period of less than 48 hours.

TEMPERATURE

The isothermal maps of Texas for the four days of the storm (fig. 3) show a general progression of the subzero area along the line of the center of greatest snowfall for the western part of the State. On the 19th the subzero area was in the northwest part of the "Panhandle," with the isotherms of 10° and 20° extending far to the south. On the 20th the isothermal lines remained about the same. On the 21st two very cold centers developed in the central part of the State, with a minimum of 4° below zero at the resort town of Kerrville, southwest of Austin. The other cold area had its center west of Hillsboro, but there the temperatures did not reach the zero point. On the fourth day of the storm, December 22, temperature conditions were modified a bit, although extremely cold weather still prevailed in all parts of the State. The pressure by the 4th day was quite high, and cold, clear weather dominated all but the eastern part of the State. Subfreezing temperatures were recorded in every town of the lower Rio Grande Valley with the exception of Point Isabel. (See Table I for minimum temperatures.)

DAILY SNOWFALL

In order to plot the movement and progress of the storm, maps were made to show the region of snowfall at the end of a 24-hour period for each of the four days. These maps do not show the snow that had accumulated from the day before, but merely map those areas having snowfall during that 24-hour period. The first day, December 19 (fig. 4), showed snowfall only in the central "Panhandle" area, with a maximum fall of 4 inches

[1] Ward: The climates of the United States, page 250.

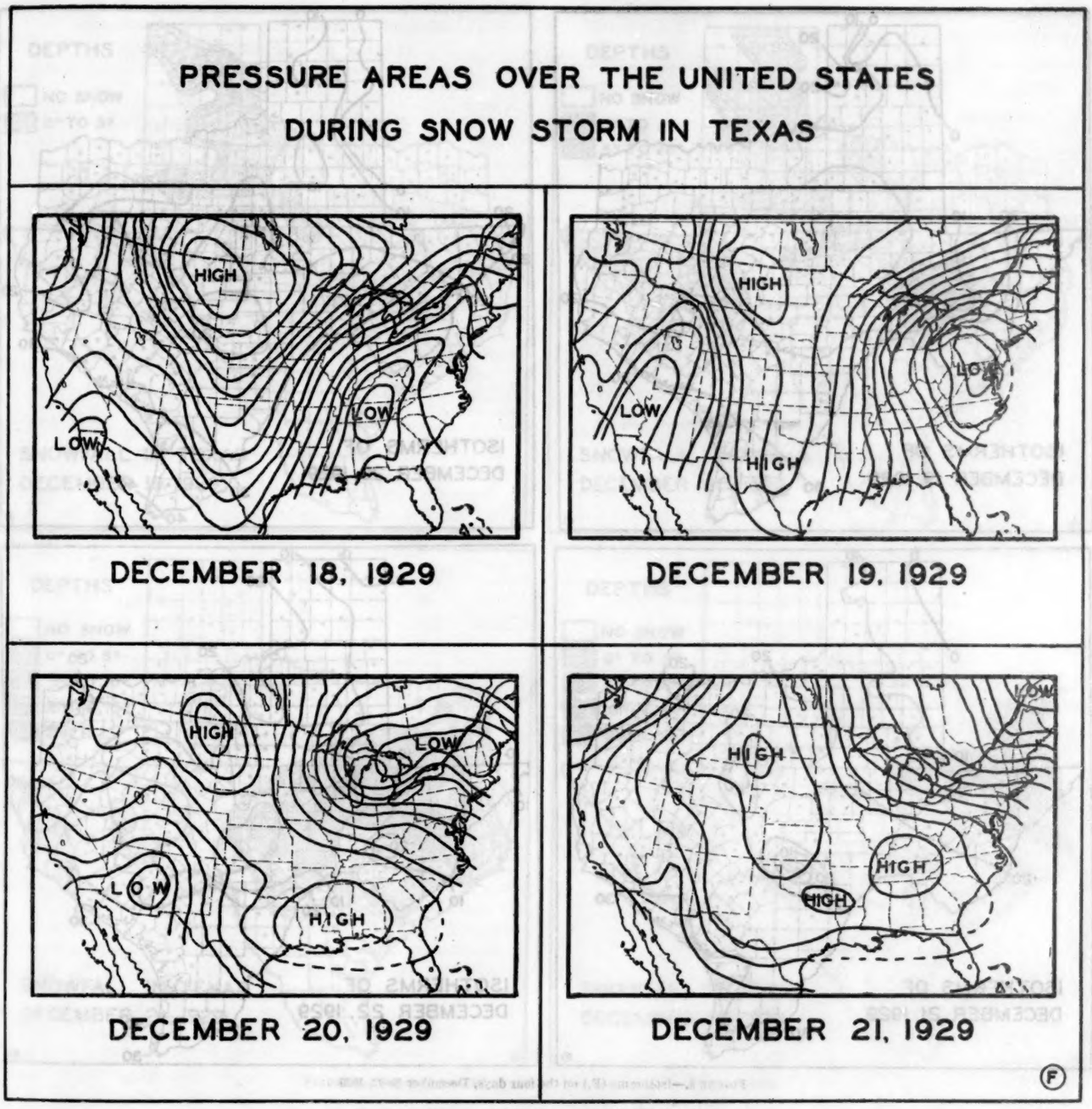

FIGURE 2.—Pressure distribution associated with the storm

around Childress. Most of this region had less than 2 inches of snow. On the second day (fig. 4) the snowstorm divided, a small part of it going to the southwest into the trans-Pecos country, giving a heavy snowfall in El Paso of over 5 inches. Most of the storm moved toward the southeast, giving a snowfall of more than 5 inches along the eastern front of the Balconese escarpment. The third day of the storm, December 21, gave the maximum snowfall for a 24-hour period. (Fig. 4.) Most of this snow fell along a line extending from Mason in the Edwards Plateau country, to Trinidad in East Texas, with the heavy spots around Mason and Hillsboro. On that day light snows fell as far south as the Gulf coast, bringing more than 2 inches to Houston and Beaumont. On the following day the snowstorm moved to the northeast. (Fig. 4.) East Texas received a heavy fall, with the maximum at Jefferson in northeast Texas, of nearly 20 inches.

TOTAL SNOWFALL

The composite map (fig. 5) of total snowfall for the four days of the snowstorm shows several pronounced features: (1) A widespread distribution of snow over most of the State; (2) a very heavy concentration along a line running from southwest to northeast through the center of the State; (3) steep gradients between near-by places, such as 26 inches in Hillsboro in contrast to 0.1 inch at Dallas, 70 miles northeast of Hillsboro; and (4) a

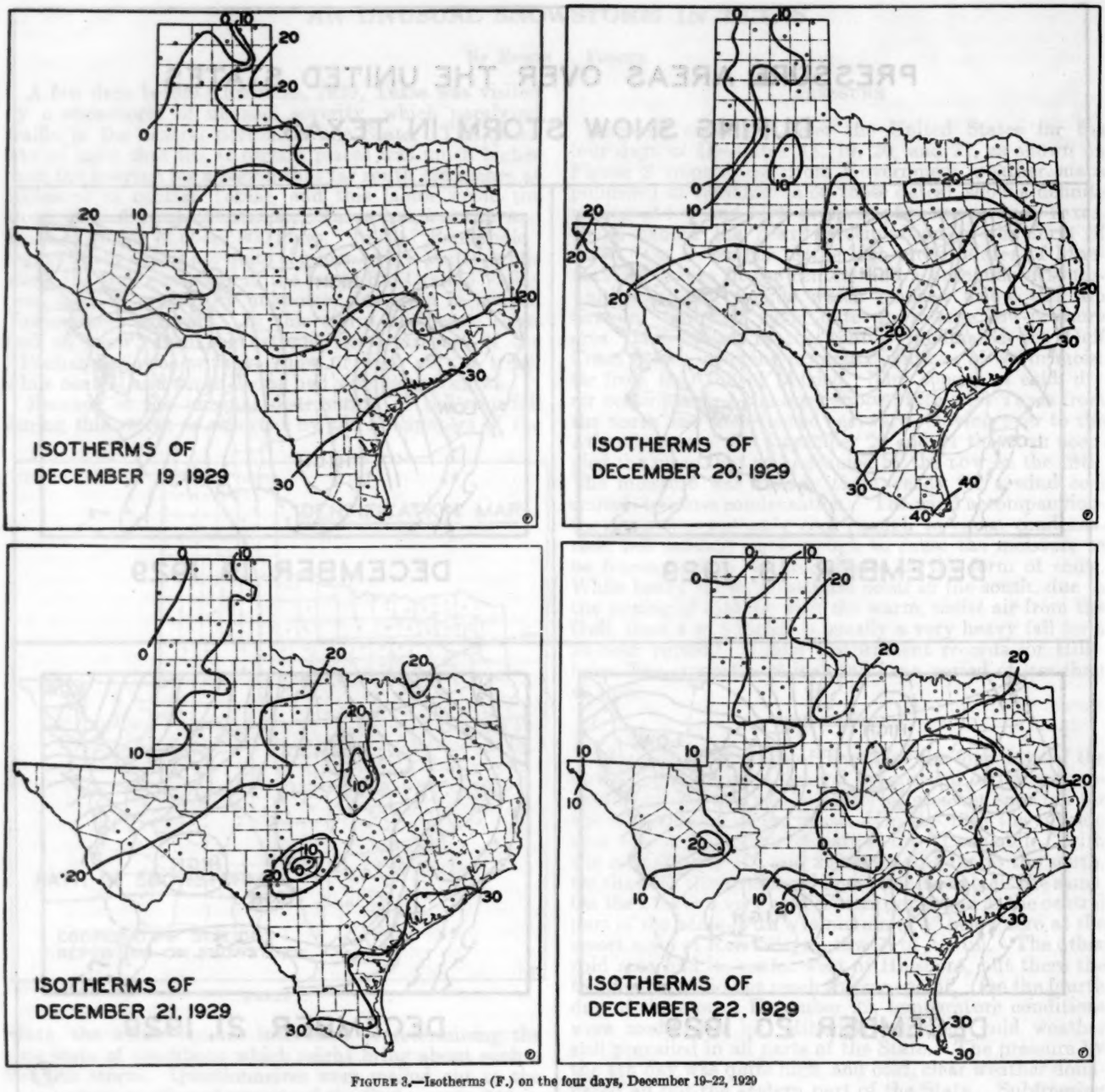

FIGURE 3.—Isotherms (F.) on the four days, December 19–22, 1929

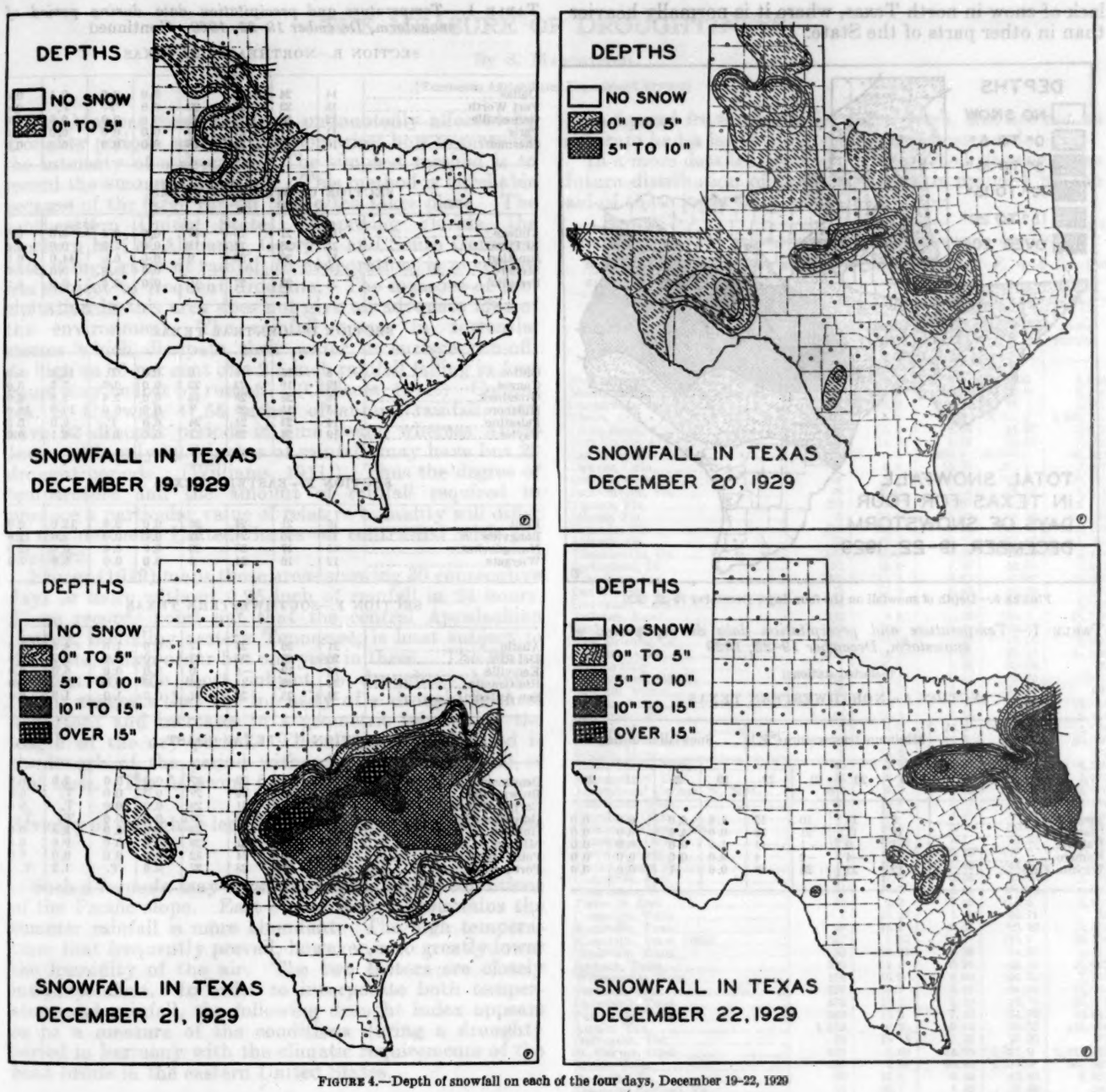

FIGURE 4.—Depth of snowfall on each of the four days, December 19–22, 1929

lack of snow in north Texas, where it is normally heavier than in other parts of the State.

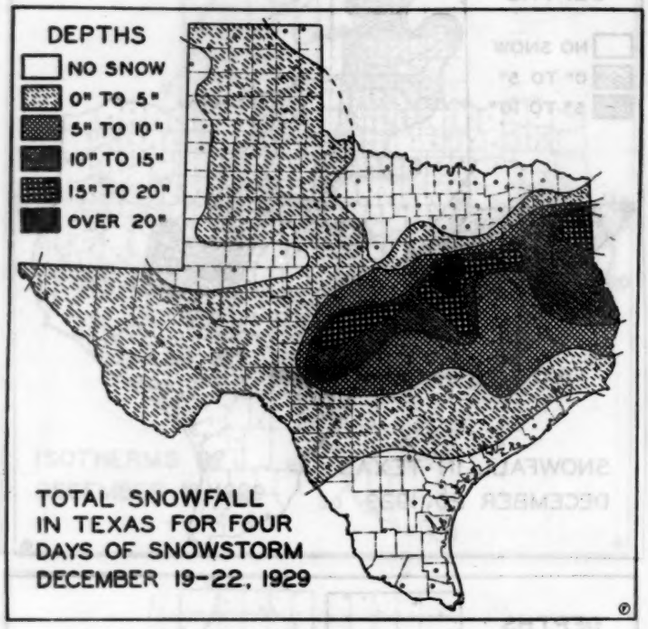

FIGURE 5.—Depth of snowfall on the four days, December 19–22, 1929

TABLE 1.—*Temperature and precipitation data during period of snowstorm, December 19–22, 1929*

(Selected stations)

SECTION A.—NORTHWESTERN TEXAS

Station	Minimum temperature (°F.)				Snowfall in inches			
	19	20	21	22	19	20	21	22
Amarillo	6	15	10	12	1.6	0.0	0.0	0.0
Clarendon	18	11	21	28	0.0	4.0	0.0	0.0
Dalhart	−1	0	−1	−1	1.5	0.0	0.0	0.0
Romero	−2	−4	−2	4	0.0	0.0	0.0	0.0
Wichita Falls	12	22	23	18	0.0	.1	0.0	0.0

TABLE 1.—*Temperature and precipitation data during period of snowstorm, December 19–22, 1929*—Continued

SECTION B.—NORTHEASTERN TEXAS

Dallas	14	24	28	19	0.0	0.0	0.1	0.0
Fort Worth	15	23	28	20	0.0	T.	T.	0.0
Gainesville	12	18	27	21	0.0	0.0	0.0	0.0
Paris	11	11	21	19	0.0	0.0	0.0	0.0
Sherman	10	12	21	18	0.0	0.0	0.0	0.0

SECTION C.—WESTERN TEXAS

Abilene	11	21	25	17	0.0	0.1	0.0	0.0
El Paso	21	23	17	15	0.0	5.2	0.0	0.0
Junction	17	20	26	0	0.0	0.0	14.0	0.0
Menard					0.0	18.0	0.0	0.0
Presidio	24	22	27	10	0.0	0.5	0.0	0.0

SECTION D.—CENTRAL TEXAS

Clifton	8	15	8	0	0.0	T.	16.0	8.0
Conroe	19	19	22	22	0.0	0.0	7.5	0.0
Groesbeck	16	25	25	13	0.0	2.4	5.6	0.0
Hillsboro	15	15	25	4	0.0	0.0	16.0	10.0
Palestine	14	23	24	24	0.0	T.	9.0	0.5
Taylor	19	24	25	13	0.0	1.5	4.1	0.0

SECTION E.—EASTERN TEXAS

Flint	16	21	24	26	0.0	0.0	12.0	0.0
Longview	15	16	24	22	0.0	0.0	2.0	12.0
Nacogdoches	15	17	23	20	0.0	0.0	0.0	12.0
Wiergate	12	16	24	5	0.0	0.0	5.0	7.0

SECTION F.—SOUTHWESTERN TEXAS

Austin	21	26	23	17	0.0	1.0	4.5	0.0
Del Rio	26	28	27	22	0.0	0.0	2.2	0.0
Kerrville	16	19	−4	0	0.0	0.0	6.0	0.0
Rio Grande	34	36	31	26	0.0	0.0	T.	0.0
San Antonio	23	25	24	21	0.0	1.0	1.9	0.0

SECTION G.—TEXAS COAST

Beaumont	24	25	29	27	0.0	0.0	2.0	0.0
Brownsville	32	39	32	29	0.0	0.0	T.	0.0
Corpus Christi	30	36	31	28	0.0	0.0	T.	0.0
Galveston	23	30	30	29	0.0	0.0	T.	T.
Houston	20	24	27	24	0.0	0.0	2.5	0.0
Mission	31	33	31	28	0.0	0.0	0.0	0.0
Point Isabel	35	41	34	32	0.0	0.0	0.0	0.0
Port Arthur	23	26	28	27	0.0	T.	1.2	T.

THE MEASURE OF DROUGHTINESS

By S. MARCOVITCH

[Tennessee Agricultural Experiment Station]

The Mexican bean beetle is undoubtedly affected by droughty periods, and the question arises how to measure the intensity of a drought. The simplest method is to record the amount of rainfall. This method is unreliable because of the large run-off that often takes place. The southeastern United States, comprising Florida, the southern half of Alabama, Georgia, and South Carolina, with a high ratio of rainfall to evaporation, is nevertheless subject to frequent droughts. The measure of precipitation in this area does not give an adequate idea of the environment. The rainfall comes in torrential storms which dissipate their water in surface run-off. As high as 80 per cent of a 2.5-inch rainfall falling in four hours may be lost by run-off. (Chilcott, 1911.) Columbia, S. C., with 47.55 inches of annual rainfall, may have 62 drought periods in nine years, whereas Ames, Iowa, with only 30.4 inches of rainfall, may have but 23 drought periods. (Williams, 1911.) Thus the degree of temperature and the amount of rainfall required to produce a particular value of relative humidity will differ in the northern United States as contrasted with the southern.

Kincer (1919) maps those areas showing 30 consecutive days or more without 0.25 inch of rainfall in 24 hours. These records point out that the central Appalachian district, including eastern Tennessee, is least subject to droughts, which occur but one year in three. The Plains sections are the most subject to droughts. Munger (1916) suggests that the intensity of a drought is most important and increases in a geometric relation to the length of the dry period. The single variable used is the length of the period without a 24-hour rainfall of 0.05 inch. The following formula is used viz:

Severity of drought = length of drought × ½ length of the drought

Such a formula may approximate the actual conditions of the Pacific slope. East of the Rocky Mountains the summer rainfall is more abundant. The high temperatures that frequently prevail, however, also greatly lower the humidity of the air. The two factors are closely interdependent. In order to incorporate both temperature and rainfall, the following drought index appears to be a measure of the conditions during a droughty period in harmony with the climatic requirements of the bean beetle in the eastern United States.

$$L \times \tfrac{1}{2} L \times \left(\frac{100}{R}\right)^2$$

Where L = the total number of two or more consecutive days above 90° F. for the months of June, July, August, and September, and R = the total summer rainfall for the same months. With this formula, the intensity of a drought is made to increase as the square of its duration, and includes both factors of temperature and precipitation. 100 is used in place of 1 in order to avoid decimals. A drought varies directly as the temperature, and inversly as the precipitation.

Localities with an index of 2,000 or less appear favorable for the bean beetle, while those above 10,000 appear too hot and dry and represent unfavorable conditions. In the following table the drought index numbers have been figured from records for three years, and are not as accurate had a larger number of years been used.

In a more detailed report to be published elsewhere the future distribution of the bean beetle is mapped by the aid of these index numbers.

TABLE 1.—*Climatic index numbers using the formula* $L \times \frac{L}{2} \times \left\{\frac{100}{R}\right\}^2$ *where* L *= the successive number of days above 90° F. and* R *= the summer rainfall*

Locality	$L \times \frac{L}{2}$	Summer rainfall	$\left\{\frac{100}{R}\right\}$	$\left\{\frac{100}{R}\right\}^2$	Index number
Birmingham, Ala.	184	16.5	6.0	36.0	5,904
Montgomery, Ala.	244	16.0	6.25	39.0	9,516
Centerville, Ala.	309	23.0	4.37	19.1	5,871
Yuma, Ariz.	3,533	1.1	90.0	8,100.0	2,861,730
Little Rock, Ark.	173	15.0	6.66	44.35	7,612
Fort Smith, Ark.	160	14.58	6.85	46.92	7,504
San Francisco, Calif.	1	.5	200.0	40,000.0	40,000
Denver, Colo.	11	6.5	15.38	237.1	2,607
Greeley, Colo.	64	5.7	17.54	306.2	19,584
Jacksonville, Fla.	96	26.0	3.84	14.74	1,421
Tampa, Fla.	292	32.77	3.05	9.3	2,715
Miami, Fla.	5	32.56	3.07	94.24	470
Orlando, Fla.	632	29.0	3.44	11.83	6,457
Atlanta, Ga.	33	16.3	6.13	37.57	1,237
Thomasville, Ga.	168	21.9	4.56	20.79	3,494
Springfield, Ill.	35	13.4	7.46	55.65	1,946
Vincennes, Ind.	205	15.5	6.45	41.60	8,528
Des Moines, Iowa	33	15.5	6.45	41.60	1,372
Lawrence, Kans.	96	17.7	5.64	31.80	3,052
Tribune, Kans.	132	8.6	11.62	134.5	16,758
Baton Rouge, La.	190	23.0	4.34	18.83	3,572
New Orleans, La.	211	23.00	4.33	18.74	3,945
Shreveport, La.	521	12.76	7.87	61.93	31,749
Mexico City	1	16.7	5.98	35.76	36
Battle Creek, Mich.	19	13.4	7.46	55.65	1,056
St. Paul, Minn.	10	14.7	6.80	46.24	460
Jackson, Miss.	416	15.7	6.37	40.57	16,848
Columbia, Mo.	56	13.8	7.24	52.41	2,934
Helena, Mont.	4	4.9	20.4	416.1	1,664
Glasgow, Mont.	30	5.4	18.5	342.2	10,260
Boston, Mass.	6	13.5	7.40	54.76	328
North Platte, Nebr.	45	9.92	10.0	100.0	4,500
Bismarck, N. Dak.	13	8.9	11.23	125.4	1,625
Agricultural College, N. Mex.	862	5.3	18.86	353.4	304,286
Columbus, Ohio	18	12.7	7.87	61.93	1,114
Hamilton, Ohio	106	14.7	6.80	46.24	4,876
Oklahoma City, Okla.	500	12.6	7.93	62.88	31,400
Muskogee, Okla.	160	13.06	7.7	59.29	9,488
Portland, Oreg.	10	4.9	20.40	416.1	4,160
State College, Pa.	7	15.0	6.66	44.3	310
Columbia, S. C.	88	17.9	5.58	31.13	2,728
Charleston, S. C.	34	17.7	5.64	31.80	1,079
Pierre, S. Dak.	49	9.2	10.86	116.6	5,684
Crossville, Tenn.	1	18.23	5.49	30.14	30
Knoxville, Tenn.	28	15.2	6.57	43.16	1,218
Knoxville, Tenn. (1925)	197	7.35	13.6	184.9	36,425
Nashville, Tenn.	50	15.01	6.66	44.35	2,217
Jackson, Tenn.	223	14.4	6.94	48.16	10,927
Wildersville, Tenn.	164	15.0	6.66	44.35	7,265
Trenton, Tenn.	326	13.6	7.35	54.02	17,604
Savannah, Tenn.	470	13.5	7.40	54.76	25,709
Perryville, Tenn.	342	13.5	7.40	54.76	18,810
Austin, Tex.	1,512	10.6	9.43	88.92	134,416
Galveston, Tex.	32	19.15	5.23	27.35	873
St. George, Utah	953	2.89	34.60	1,197.0	1,140,741
Moab, Utah	500	2.87	34.84	1,211.0	605,500
Roanoke, Va.	66	15.3	6.53	42.64	2,811
Diamond Springs, Va.	16	23.7	4.22	17.80	284
Fort Laramie, Wyo.	71	4.9	20.4	416.1	28,536
Border, Wyo.	5	4.7	21.3	453.6	2,268

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DISCUSSION OF A. STREIFF'S "THE PRACTICAL IMPORTANCE OF CLIMATIC CYCLES IN ENGINEERING" [1]

By J. W. SHUMAN, M. Am. Soc. C. E.

I should like to comment briefly on the work done by Mr. Streiff, as evidenced by his contributions to this REVIEW. In July, 1926, Streiff came forward with a complicated mathematical exposition of curve "smoothing," leading to a new method of separating the component elements of a rainfall or run-off graph. This article also pointed out a correlation between Wolf numbers, run-off, and lake levels, and ended with one example of treating river run-off data. Various cycles were derived from the river run-off graph, including Brückner cycle, 11-year cycle, and cycles of 3 years, 1.63 years, 12 months, 6 months, and a variable cycle of 2 to 5 months. Some months later an article appeared in the REVIEW, written by a well-known engineer, attacking this concept of Streiff's, of cycles in rainfall and run-off data, and claimed, in substance, that there was nothing to the idea, that there were no cycles in rainfall data, and that it was extremely improbable that run-off could be predicted by any such means.

Streiff's second article appeared in the March, 1928, number of the REVIEW, entitled "Notes on Estimating Run-off." This article followed up his first study, in a practical manner, and gave a concrete example of application of his "Strato" Analysis to the Manistee River in Michigan. This time, however, Streiff has shortened his procedure by combining the 11-year, 3-year, and 1.63-year cycles all into one residual, called residual "*e*." (Please note one typographical error in March, 1928, article—the residual "*c*" in second line of seventh paragraph from top of first column, page 99, should be, residual "*e*.") This article put the matter in such shape that it could be easily followed by anyone interested who desired to investigate for himself.

Streiff's third article appeared in October, 1929, and shows in considerable detail just why these faint cycles in our weather elements are useless for day-to-day weather forecasting, but are invaluable aid, in hydrological studies, coining a new expression "Climatic engineering."

I give the above brief sketch to point out the fact that it is now nearly four years since the initial appearance of Streiff's cycle ideas, and yet seemingly few hydrologists have made due investigation of the subject. It is true that there are selected groups here and there who are studying into these modern methods, but the rank and file are still plodding along, using the old reliable accepted theory of chance for occurrence of run-off and floods.

I wish to commend Mr. Streiff for his ability and mental powers, the results of which are now given to the profession at large. Streiff's first article made a great impression on the writer. Since then his methods of analysis have been sufficiently studied to use them with confidence. Until one is willing to actually go through with one of these analyses step by step and see the cycles emerge from the raw data only a faint conception can be had of what really can be accomplished.

There appears to be some skepticism of the Brückner cycle being in truth the double sun-spot cycle that, although the same cycle can be derived from rainfall and run-off data, it may not necessarily have any relation to the sun-spot cycle. Further testing and trials with various rainfall and run-off data will doubtlessly settle all such differences of opinion as time goes on. Personally, the writer has investigated at least three rainfall stations in every State in the Union and in a great many in Europe and has found the Brückner cycle, as pointed out by Streiff in every such station. It is true the amplitude of the cycle is sometimes very slight. But in this case it can be magnified by proper multiplication, with a large constant, to bring its swings into visibility. This double sun-spot cycle derived from the Wolf numbers, then, furnishes us with a pattern curve, with which comparison can be made by similar curves derived from rainfall and run-off data.

The writer can also testify as to use this analysis can be put to in considering lake levels. In March, 1928, the writer made a "Strato" analysis of the levels of Lake Ontario, taking the monthly mean levels as listed by the district engineer's office at Detroit. The mean level for the year 1927, was 245.55; and a letter was sent to Mr. Alfred J. Henry, editor of the MONTHLY WEATHER REVIEW, early in April, 1928, predicting that the mean level for the year 1928 would be 245.90. The level for the year actually turned out to be 246.20. In a letter written in April, 1928, to Lieut. Col. George B. Pillsbury, then district engineer at Detroit, the statement was made: "In addition to predicting the 1928 mean level of Lake Ontario, I also venture to state that the 1929 mean level will be at least equal to the 1928 mean level, if not actually higher."

In view of the writer's own experience, then, he urges hydrologists to study these articles in good faith and to peruse the subject until a working insight is gained. With the acceptance of these principles, we are now provided with means of forecasting a year ahead of time a river run-off, water supply, etc. The next great step is to study the monthly peaks of rainfall and run-off. When we can foretell their occurrence as well as we can the total run-off for the year we shall then have the question of floods solved. I may point out some of the difficulties that stand in the way of our understanding of the subject.

The peaks of rainfall or run-off occur 2, 3, 4, or 5 months apart, when isolated out of the original graph, and constitute the "Clough" cycle—a variable cycle of a mean value of some 28 months. It may be accepted that this cycle is due purely to fortuitous storms, and hence can not be further understood, or that it may follow in sequence some "cause" of approximate periodicity. Whatever the facts are, we do know that the peaks of this cycle mean higher than normal values for the data.

Streiff shows the reduction of the original monthly mean run-offs to a residual "*e*." The mean ordinate of this residual "*e*" for the year represents the mean monthly flow. But the value of any monthly ordinate of this residual "*e*" does not necessarily represent that particular month's mean flow. If $R1, R2, R3, \ldots R12$ represent the 12 ordinates of the residual "*e*", and $a\,1$, $a\,2$, $a\,3$, . . . $a\,12$, the difference between each monthly mean flow and the residual ordinate, we have—

$$(R\,1+a\,1)+(R\,2+a\,2)+\ \ldots\ (R\,12+a\,12)=\text{total year's run-off.}$$

But

$$R\,1+R\,2+\ldots R\,12=\text{total year's run-off.}$$

Hence,

$$a\,1+a\,2+\ldots a\,12=0.$$

[1] Monthly Weather Review, Oct., 1929, vol. 57: 405-411.

We note that the run-off at each month is made up of a residual plus a variable (*a*), which may be plus or minus in value, and the only thing we know about these variables is that their sum for the year is zero.

The Clough cycle probably does follow a similar cycle in the sun-spot numbers, but the correlation coefficient between the rate of change of sun-spot numbers and this variable cycle in run-off is only between plus 0.50 and plus 0.60—not good enough to work with.

It is the hope of the writer that these articles of Streiff will prove a stimulus to the profession, who owe it to themselves to at least investigate what might be to their benefit. Possibly within 10 years' time we will treat with simplicity what seems to us now a hard nut to crack.

FURTHER STUDIES ON THE ELECTRICAL CHARGES OF THUNDERSTORMS (A REPORT OF PROGRESS)

By J. C. JENSEN

[Nebraska Wesleyan University, Lincoln, Nebr., December 26, 1929]

Increased interest has been shown in the phenomena connected with lightning discharges during the last three years, due to the controversy between Simpson and C. T. R. Wilson in England and to the tremendous property losses caused by lightning in the United States. It should be remarked also that in the background behind any investigation of this kind is its relation to the earth's negative charge.

Simpson, in 1909, proposed what is known as the "breaking-drop theory" of the origin of electricity in thunderstorms which depends on rapidly ascending currents of air in a thunderhead and the observed fact that when a drop of water is broken up in the air the drop becomes charged positively and the air negatively. Raindrops from the active portion of such a cloud should carry positive charges and those from its more remote portions negative ones.

C. T. R. Wilson, by the use of an insulated ball and a capillary electrometer, succeeded in measuring the changes in the earth's field due to lightning and gave a ratio of 1 to 1:56 for positive to negative discharges. The more recent investigations by Schonland and Craib in South Africa (1), (4), (5), with apparatus essentially similar to Wilson's, give results in good agreement, both of them holding to the opinion that the lower pole of a thundercloud carries a negative charge.

In May, 1926, Simpson published a paper in which he maintained that a lightning flash originates only in the region of the maximum positive electric field and that any branching of the discharge will be in the direction of the seat of negative charges. He used as evidence on this point a large number of photographs of lightning flashes, of which 328 indicated that they were from positive clouds and 89 from negative. In April, 1927 (2), and more recently in November, 1929 (3), he gave a revised and amplified version of his theory of thunderclouds, in which he shows that the space charge of cloud should be positive in the active vortex, but that by far the larger portion of it should be negative. Lightning discharges are divided by him into three groups—(*a*) upward discharges from the head of the ascending air currents; these are thin, usually hidden by the cloud, and, if seen, would be branched upward. (*b*) Downward discharges from the same region, also thin, and branched downward. (*c*) Heavy flashes from the ground upward to the more quiescent part of the cloud. Where branching can be seen these are branched upward.

Our present series of observations at Nebraska Wesleyan began more than five years ago. Two papers have been read before this society (6), (7), and one before the American Physical Society (8), all in the nature of progress reports, for the problems involved are many and difficult of solution. The apparatus used consists of an insulated metal deck 9 meters above the earth, on the roof of the gymnasium which is adjacent to the physics laboratory. The deck is about 3 by 4 meters in size and has a capacity of 0.0014 microfarad. Adjacent to the deck is an insulated wire rectangle of the same dimensions as the deck and having a capacity of 0.0007 microfarad. Wires connect these conductors to earth through a sensitive galvanometer. A right-angle prism and rotating drum are used for making the records, the pencil carried by the parallel rods being kept over the spot of light by the observer. The capacity of the system and the ballistic constant of the galvanometer having been determined, the change in potential of the deck due to a given discharge may be computed. Values of changes in the potential gradient thus obtained have been consistently lower than those of other observers, due to tall trees and other surrounding objects.

In order to be able to identify a given discharge with the corresponding galvanometer deflection, a pair of telephone wires was run to the top floor of an adjoining 4-story building which presents a good view toward the western horizon. At the instant of a flash, word is sent to the observer in the laboratory, who records the data given on the drum. Differentiation is made between flashes from cloud to cloud and from cloud to earth. Notations are entered in a notebook of each lightning discharge regarding distance to cloud, size of flash, part of cloud from which flash came, etc. Likewise, when photographs have been taken, notes taken at the instant are used, together with the drum record and synchronized watches, to identify the picture.

During the season of 1928 observations were made on a total of 19 storms, 11 of which were in daytime and 8 at night. A total of 1,014 galvanometer deflections resulting from lightning discharges were recorded, 639 of which indicated a decrease of negative potential above the apparatus and 375 an increase of negative or a decrease of positive. Classifying as "distant" discharges beyond 8 kilometers and as "intermediate" those from 5 to 3 kilometers, the totals are 177 negative to 122 positive for distant discharges, 171 to 67 for the intermediates, and 298 to 196 for the "near" ones. It has here been assumed that our clouds hang lower than those observed by Schonland in South Africa, hence the reversal distance should be less than the 6.8 kilometers which he found. The fact that the ratio is larger for the intermediates than for the near ones would indicate either that this assumption is not well founded or that Wilson's theory does not account for all the facts. It should also be noted that the observations made prior to 1928 totaled 639 negative to 375 positive, a ratio practically identical with the more recent one, although no special efforts to check on distances were made in the earlier readings. Wilson's totals in his earlier paper gave a ratio of 1 : 1.56, positive to negative, while my present aggregates of 1,096 and 1,979, including the 1929 season, give a ratio of 1 : 1.80. In view of the radical difference in method

used and the climatic differences between London and Lincoln, this is very good agreement, and would seem to justify a statement that this work supports Wilson's contention that the upper pole of the cloud is positive. However, the exceptions to the general average are so marked that they must be given careful consideration. For example, storm No. 19 on September 19, 1928, did not get nearer than about 5 miles at any time during the first hour that it was under observation and must be classed as a "distant" storm. Yet the record gives 128 discharges showing the lower pole negative to 33 positive. In the interval from 9:34 to 9:58 p. m. of that storm the ratio was 23 to 0 for the lower negative polarity. These conclusions are both on the basis of a bipolar cloud beyond the reversal distance. On Schonland's theory of reversals the ratio should have been reversed or the upper pole of the cloud must have been negative. Storm No. 5 on June 23, 1928, shows a ratio of 18 to 2 during the period from 12:46 to 1:12 a. m. for lower pole *positive*, the storm being directly overhead. This agrees nicely with Simpson's theory if we *knew* that the vortex was passing over at that time, *but* the ratios became even larger in the same direction as the storm passed on, which can not well be reconciled with the Simpson picture.

My galvanometer usually shows a continuous shift to right while rain is pouring down, and ballistic throws following lightning flashes are to left at the same time. This fact can be explained by recalling that the metal deck would collect the charges on the falling drops, deflection to right corresponding to negatively charged rain and left throws resulting from positive charges going to earth. The storm of June 23, referred to above, gave a shift to the left, as should be the case according to either theory, Simpson's or Wilson's. That the galvanometer shift is really due to the falling rain is proved by switching from the metallic deck to a wire rectangle of the same area but about one-half the electrostatic capacity. The rectangle reduces the shift almost to zero while still giving large deflections due to discharges.

The general trend of the evidence obtained is in favor of the Simpson theory for the cyclonic type of storm, but to account for some of the records we must assume that the positively charged vortex is much larger in some storms than in others; also that some storms move much more slowly than the rates usually given, 30 to 50 kilometers per hour, and may remain almost stationary for an hour or so until most of the energy they contain is dissipated.

It is obvious that if Simpson's picture of the distribution of charges in the thundercloud is correct there should be a brief period when the storm is approaching close by, and when its front is directly overhead, when instruments such as have been used by any of the observers to date should indicate a preponderance of positive charge overhead. This charge should be reduced by each lightning flash, only to be built up again by the action of the air currents in the storm. This would apply also to Norinder's method (**9**) of triangulation, as his stations were so close to each other as to be well within Schonland's reversal distance. Following this positive portion would come a much larger section of cloud in which the negative charges would predominate. Since change-of-potential readings have been taken for the whole cloud, and without regard to whether the storm passed directly over the observer or to one side, the large ratio of 1:80 to 1:00 for the lower pole of cloud negative is, in fact, in agreement with Simpson's theory. To maintain even so large a proportion of charges from a positive cloud as we have it is necessary that this part of the storm be much more active than the other.

D. Nukiyama and H. Noto (**10**) have recently suggested that the thunderstorms found inland in Japan are of the Simpson type while those along the seacoast conform to the Wilson bipolar scheme with lower pole negative. These observers are using a galvanometer system similar to mine, with the added advantage of a photographic recording device, but state that their total number of observations is too small to warrant any general conclusions. In a later paper Noto (**11**) reports both negative and positive fields, and leans to the dipole pattern. In this instance, also, the conclusion is drawn from meager data and could as well be accounted for by Simpson's type of cloud as shown by some of the type cases studied theoretically by Simon (**12**).

Simpson has suggested the desirability of obtaining pictures of lightning flashes with the corresponding data regarding field changes. He points out the necessity of knowing definitely what part of the storm is overhead the instant when a given field-change observation is recorded. We have met the first of these requirements by taking a number of pictures concerning which the field-change data is also on record and find that in the active front of the cloud most of the discharges to ground are forked downward, as required by Simpson, and that in the secondary part, the other type with branches upward, predominates. Our pictures disagree with Simpson's requirements that flashes from the positive part of a cloud are thin, as these are the brightest and hottest discharges we have.

To learn the rate of motion of the storm, whether its center has passed over the observer, the rapidity and magnitude of the pressure changes connected with different parts of the storm, etc., four Tycos microbarographs have been secured. One is in the laboratory at Nebraska Wesleyan, one about 3½ miles south in College View, and the third 5 miles north on the hills north of Salt Creek. A fourth is in the Lincoln Weather Bureau office. These instruments were made available through grants from the Hodgkins fund of the Smithsonian Institution, and from the University of Nebraska, and the loan of one from the United States Weather Bureau at Washington. They were put into service on July 22, 1929. The month of August was dry and lacking in well-developed storms at Lincoln, but records obtained give promise that the instruments are capable of doing the work required of them and that the mooted questions to the present controversy may be put to a crucial test during the coming thunderstorm season.

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NOTES, ABSTRACTS, AND REVIEWS

Severe dust storms over Idaho, Washington, and Oregon.—On March 19, 1930, an exceptionally severe dust storm occurred in the inland empire of eastern Washington, Oregon, and northern Idaho. The weather map of that date shows a strong HIGH over western Oregon and adjacent Pacific Ocean with a LOW in southern Alberta. This distribution of pressure is the ideal condition for a chinook, but, owing to drought and previous warm weather, there was no snow to melt on the lowlands and the moisture was quickly evaporated from the top soil, allowing dust to be picked up in great quantities. The velocity of the wind exceeded 30 miles an hour at times.

The writer collected samples of the dust that had fallen on a clean paper held flat by weights that lay on a table on a screened porch. The dust weighed 2.03 grams per square foot. Dust deposits in front and at the back of the house were nearly double the amount given, but were disregarded, since it seemed that they might be above average and a conservative result was desired. The deposit of 2.03 grams per square foot equals 62 tons per square mile. Assuming that the inland empire had 50,000 square miles affected by the storm and that the fall of dust at Cheney was an average of the whole region, some 3,000,000 tons of dust were deposited. Allowing 60 tons per freight car and 100 cars per mile, it would take a freight train 500 miles long to move the dust that the storm moved in about eight hours; or, since a cubic yard weighs about 1 ton, the dust would make a column 1 square yard in cross section and 1,700 miles high.—*O. W. Freeman, State Normal School, Cheney, Wash.*

Snows do not govern crops.—According to E. R. Henson, assistant professor of farm crops at Iowa State College, heavy snowfall does not necessarily mean a bumper crop the next year.

Experiments have proved that soils can only hold a certain amount of moisture and when that amount is attained any additional moisture moves on down through the soil, finally drain off underneath.

These experiments have shown that soil can hold only about 1½ inches of water per foot of depth. As the roots of plants normally are largely in the surface 7 inches of soil and the entire system seldom penetrates beyond the 4-foot line, the water that the soil can hold at any time within the reach of plants is equivalent to only about 6 inches of rain.

In sections where rainfall is not abundant, heavy snow furnishes an ideal source of moisture and good crops may follow. In sections such as Iowa, however, where rainfall is usually abundant and the soil often already has its quota of moisture, the moisture from heavy snows will merely drain off. Where this happens, the soil is often depleted in fertility because of the possibility of the excess moisture carrying off large quantities of calcium and nitrogen together with lesser amounts of phosphorous and potassium. Heavy snowfall and excess moisture may, then, be a detriment in some seasons in Iowa, while in other years it is a great benefit.

Nine waterspouts near Equator.—Second Officer E. S. Bryant, of the British steamer *Oilshipper*, reports that between 1 and 2.30 p. m. (ship time) on February 23, 1930, in latitude 8° 49′ N., longitude 84° 41′ W. (off Pacific coast of western Panama), nine waterspouts were observed, the nearest being about one-half mile distant. The formation, which was common to all, appeared to commence at the surface of the sea under a low bank of nimbus cloud. A few minutes later a tapering cloud formation gradually dropped, increasing in length, at an angle toward the agitated area on the sea. This had the appearance of a whirlpool with an anticlockwise motion. The spray around the base of the spout was caught in the whirl and carried upwards for about 50 feet. Throughout the duration of the spout there was no visible connection between the whirl on the sea and the lower part of the column of cloud, which extended about two-thirds of the distance to the sea. The peculiar effect suggested that the tapering cloud formation was hollow and was characteristic of all the spouts. The weather at the time was calm with a smooth sea, although all the waterspouts were moving at a fair rate to the east-northeastward. The temperature of the air was 82° F.; of the sea, 86°; barometer, 29.86 inches.—*Hydrographic Bulletin, Washington, D. C. March 19, 1930.*

Forecasting Mean Winter Temperatures for the North American Interior; by Chas. F. Brooks.—Application of the Groissmayr formula, based chiefly on summer weather in India, 1929, indicated a plus departure of 1.4° F. in mean temperature for Winnipeg from December, 1929, to February, 1930, inclusive. (MONTHLY WEATHER REVIEW, November, 1929, p. 454.)

Through the courtesy of Director Patterson, of the Canadian Meteorological Service, we learn that the mean for these months at Winnipeg was 2.9° F., or 1.6° F. above a 20-year normal, and 2.2° F. above the (1873–1920) normals in "World Weather Records" (Clayton). This successful forecast makes the sixth forecast based on Groissmayr's formula founded on earlier years of record. Of these six, two were nearly perfect, two reasonably successful, one good, and one poor. M. W. R. p. 455.)

The forecast formula can not be said to give any more than simply the mean temperature. This forecast of the past winter as one averaging slightly above normal would hardly have led one to expect the moderately cold December and January, 1.9° and 3.4° F. below normal, and the extraordinarily warm February, 11.9° F. above normal. Is a forecast simply of the mean temperature for the three months together of any value?

Air-Mail Pilot Encounters Severe Thunderstorm in Florida, by James W. Smith.—Air-Mail Pilot F. B. Cann encountered a thunderstorm of unusual intensity over east-central Florida the afternoon of March 23. Pilot Cann took off from Daytona Beach at 4:35 p. m. with the southbound air mail. The ceiling was low, 600 to 800 feet, and a light rain was falling at the time. Reports from southern Florida indicated fair weather, and no reports were available from other regularly reporting stations along the route, due to the fact that the plane was several hours behind schedule.

The rain increased from light to heavy and soon it was impossible to see the ground from above 300 feet. The air became very rough, with strong vertical currents, and, considering the poor visibility due to the heavy rain, Mr. Cann thought it safer to gain altitude and fly blind, which he did, at the 1,000-foot level. The rain was uniformly warm and no hail or lightning observed, although thunder crashed heavily on two occasions. Such severe storms are unusual at this season, and it seemed better to "stick it out" for a few minutes than to go back through the weather just experienced and land at Daytona Beach.

The storm lasted to just south of Titusville, requiring 30 minutes for a portion of the trip ordinarily covered in 22 minutes. Here the rain stopped and the dense clouds abruptly broke away, leaving the sun visible through a layer of high thin clouds. The storm passed quickly out over the ocean and rapidly whipped up a rough sea. On the fringe of the storm over Indian River Mr. Cann counted 15 whirlwinds which picked up water from the

111758—30——3

wave crests, but none of which attained the proportions of a water spout. Seeing some fishing boats, he flew low enough to warn them of the approaching storm, then continued south to Miami.

A check-up on the plane after landing showed that paint had been removed from the more exposed portions as though by a sand-blast, and the forward edge of the steel propeller was nicked and eroded to such an extent that it was necessary to order a new one. Pilots and mechanics of the Miami airport agreed that they had never before seen a propeller so damaged by rain. The asbestos packing was washed from the gaskets and the cockpit was soaked, which is unusual even in a heavy rain, although the mail, which was in a closed double-bottomed cockpit, escaped injury.

Mr. Cann had at no time expected the storm to be so severe nor of such long duration, and states that in the event of meeting another he would immediately land the plane, if possible.

A low-pressure area, about 29.75 inches, was central over Florida at the time, and the 8:00 a. m. reports from near-by stations the following morning showed heavy rainfall: Jacksonville, 2.34 inches; Orlando, 3.48; Eustis, 1.34; Titusville, 1.68; and Sanford, 1.01.

Speed record airplane flight, Ralph Sanders.—On March 2, 1930, Pilot Frank J. Andre, flying the air mail, took off from Atlanta at 3:30 p. m., arriving at Macon at 3:55 p. m. The distance of 77 miles (airline) was covered in 25 minutes, averaging 185 miles per hour.

Line Superintendent A. P. Kerr left Macon at 1:20 p. m. and arrived at Jacksonville at 2:35 p. m., flying an airline distance of 210 miles in 75 minutes, an average of 168 miles per hour. (The pilot's report and field manager's time report disagreed by 10 minutes. On pilot's log, arrival time is 2:25 p. m. Departure from Macon agreed on both reports. If the pilot's time, 65 minutes, were used the average speed would approximate 200 miles per hour.)

On the flight from Macon to Jacksonville the pilot reported that below 6,000 feet the air was unusually bumpy, but at 7,000 feet, which altitude he held, it was quite smooth. The balloon runs made at Atlanta (12:10 p. m.) and Jacksonville (3:00 p. m.) yield the following information:

6,000 feet: Atlanta wind northwest, 56 miles per hour; Jacksonville wind west-northwest, 45 miles per hour.

7,000 feet: Atlanta wind northwest, 76 miles per hour; Jacksonville wind west-northwest, 56 miles per hour.

8,000 feet: Atlanta wind northwest, 94 miles per hour; Jacksonville wind west, 63 miles per hour.

Since the wind backed toward west as the plane from Macon approached Jacksonville, giving cross rather than tail winds, with an appreciable decrease in velocity, the reason for the greater speed of the plane from Atlanta to Macon over the one flying from Macon to Jacksonville is apparent.

These two flights are record flights for speed. Eastern Air Transport states that these planes have a maximum speed of 135 miles per hour, with a generally used cruising speed of 110 miles per hour.

On the same date as the other two flights Pilot Eugene R. Brown took off from Atlanta at 9:05 a. m. for Greensboro, arriving at 11:05 a. m. The airline distance of 307 miles was made in two hours, an average speed of 153 miles per hour.

The 6:10 a. m. balloon run at Atlanta shows a surface wind of 25 miles per hour from west-northwest, steadily and rapidly increasing to 78 miles per hour from northwest at 7,500 feet, decreasing to 67 miles per hour from the west at 8,200 feet, then increasing again to 90 miles per hour from the west at 10,800 feet. This gave the pilot strong cross winds, which hindered rather than helped, but he was helped by the wind shifting toward the southwest as the plane approached Greensboro, as shown by the following data taken from the 6:04 a. m. balloon run at that place: Surface west-northwest, 10 miles per hour; 6,000 feet west, 51 miles per hour; 7,500 feet west-southwest, 54 miles per hour; and 8,000 feet west-southwest, 56 miles per hour.

The above information, with the exception of the wind data, was furnished by Mr. E. V. W. Jones, editor of New Wing, published by Eastern Air Transport, owner of the planes.

Pilot Wheaton's Experience Against Terrific Head Winds, by L. A. Warren, Cheyenne Airport.—Pilot H. A. Wheaton, flying the morning westbound mail out of Cheyenne on March 22, 1930, relates the following experience against terrific head winds.

Leaving Cheyenne about 5 a. m. he attempted to fly the usual course over Sherman Hill, a point about 30 miles west and approximately 3,000 feet higher than Cheyenne. His air speed was calculated at from 90 to 100 miles per hour, but the head winds he encountered were of such force as to cause the plane to actually drift backward. Seeing that he was making no progress against the wind he turned back and flew over the mountain range several miles south and at a lower height. The winds there were of high velocity, not too strong, to prevent a very slow progress.

High winds from a westerly direction are frequently encountered over the Sherman Hill Pass, but not often of such velocity as to prevent at least a slow movement against them.

Changes in the Daily Weather Report of the London Meteorological Office. [*Condensed from the Meteorological Magazine, Meteorological Office, Air Ministry, London, March, 1930.*]—Due to rather drastic revision in the international exchange of meteorological information brought about at the Conference of Directors of Meteorological Services at Copenhagen in September, 1929, the London Meteorological Office deemed it advisable to change the form of the Daily Weather Report issued by that office so as to include, beginning March 1, 1930, a weather chart for the Northern Hemisphere for the morning of the date of issue. The dimensions of this new chart are substantially 12 by 12 inches, a small reduction in size from the one previously issued. The pressure distribution is shown by isobars drawn for an interval of 4 millibars (0.12 inch); temperature, in degrees Fahrenheit, is printed on the chart, as are also wind direction and force and the state of the sky by appropriate symbols.

The only serious hiatus on the chart is the absence at times of reports from about a quarter of the Northern Hemisphere, say, from 100° to 180° east longitude. It may be, however, that means of communication with Siberian stations along and north of the fiftieth parallel of north latitude are not yet as fully developed as may be possible.—*A. J. H.*

Climatic cycles in the Eocene.—A geological paper of more than usual interest to climatologists is "Varves and Climate of the Green River Epoch; by Wilmot H. Bradley.[1] This is a study of marlstone, oil shale, and fine-grained sandstone from lake beds of middle Eocene

[1] U. S. Geological Survey, Professional Paper 158-E, Washington, 1929.

age (first of the five subdivisions of the Tertiary) in Colorado, Utah, and Wyoming.

These rocks consist of varves, not glacial but biochemical in origin. Each varve consist of two laminæ, one of ooze that has lithified into oil shale, the other of calcium and magnesium carbonate such as is now being deposited as marl in many lakes. From analogy with modern lake deposits it is argued that the carbonates were precipitated in early summer, the oil shale later in the hottest season, and that these sediments were still more sharply separated by differential settling. Study of the sandstone layers suggests that the climate was marked by a well-defined winter rainy season, and examination of plant remains indicates temperatures and rainfalls similar in amount to those now prevalent in Louisiana.

In addition to the bilaminal annual cycle, recurrent groups of thick varves show an average interval of a little less than 12 years, with individual intervals ranging from 7 to about 18 years.

An average cycle of 21,630 years resulted from measurements on four groups of alternating beds of oil shale and marlstone, affording 16 cycles. Croll's hypothesis, it will be remembered, was based on a cycle of about 21,000 years, the resultant of the cycle of the precession of the equinoxes in 25,000 or 26,000 years, and the revolution of the line of apsides, in the opposite direction.

A third cycle, of about 50 years, is represented by regularly recurrent layers of calcite-filled cavities that are supposed to have originally been filled with a salt-like glauberite. This corresponds to no well-established rhythm.

Climatologists will envy Bradley his wealth of material. From measurements of varves he estimates the Green River epoch to have lasted between five and eight million years.—*Eric R. Miller.*

Padua, Italy, precipitation, 1900–1928.—A correspondent asks us to print the continuation of the Padua record of annual precipitation that was given in the article by Robert E. Horton on "Group distribution and periodicity of annual rainfall amounts, this REVIEW, 51: 514–521. This we do in the following table:

Total annual precipitation (millimeters) [1]

1901	1,029.7	1915	943.3
1902	851.1	1916	1,131.9
1903	800.3	1917	742.1
1904	794.2	1918	971.1
1905	1,140.5	1919	875.5
1906	818.5	1920	910.1
1907	714.4	1921	429.6
1908	566.0	1922	691.7
1909	715.1	1923	752.6
1910	1,075.4	1924	878.4
1911	906.6	1925	728.1
1912	762.1	1926	741.2
1913	860.4	1927	798.1
1914	773.1	1928	835.6

Meteorological summary for Chile, February, 1930 (by J. Bustos Navarrete, Observatorio del Salto, Santiago, Chile).—The weak atmospheric circulation over the Pacific and the scantiness of rain noted in January continued during this month. In the first decade depressions of minor importance crossed the extreme southern region and were accompanied by scattered rains between Magallanes and Valdivia, with maximum amounts on the 3d and 4th. Thereafter the weather was settled in high degree over the entire country. Two anticyclones of major importance were charted as follows: 17th–18th, moving from Chiloe toward Argentina, and 25th–28th, moving from Magallanes northward.—*Translated by W. W. R.*

[1] Record by months in Sitzungsberichte der kaiserlichen Akademie der Wissenschaften. III. Abt. IIa. 1902.

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SOLAR OBSERVATIONS

SOLAR AND SKY RADIATION MEASUREMENTS DURING MARCH, 1930

By HERBERT H. KIMBALL, Solar Radiation Investigation

For reference to descriptions of instruments and exposures, and an account of the method of obtaining and reducing the measurements, the reader is referred to this volume of the REVIEW, page 26.

Table 1 shows that solar radiation intensities averaged below the normal intensity for March at all three stations.

No skylight polarization measurements were obtained at Madison during the month. At Washington measurements obtained on four days give a mean of 58 per cent and a maximum of 61 per cent on the 5th. These values are close to the corresponding averages for Washington.

NOTE.—The data for Table 2 will appear in the next issue of the REVIEW.

TABLE 1.—*Solar radiation intensities during March, 1930*

[Gram-calories per minute per square centimeter of normal surface]

Washington, D. C.

Date	Sun's zenith distance: 8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass: A. M.					P. M.				Local mean solar time
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Mar. 4	1.60		0.68								1.45
Mar. 5	3.15	0.64	0.74	0.90	1.14	1.44					3.00
Mar. 13	3.81		0.68	0.81	0.99	1.27					4.37
Mar. 14	2.36			1.02	1.33						2.06
Mar. 15	1.68	0.63	0.73	0.85	1.02	1.28	0.94	0.71			1.52
Mar. 20	3.99			0.93	1.12	1.46	0.92				3.00
Mar. 21	5.36						1.18				3.15
Mar. 22	1.68					1.50	1.23	0.89			1.96
Mar. 24	4.17	0.54	0.63	0.77	1.03	1.49					5.56
Mar. 26	2.26				0.89						2.26
Mar. 31	3.15		0.59	0.77	1.15	1.36					2.87
Means		0.60	0.68	0.86	1.08	1.40	1.07	(0.80)			
Departures		−0.12	−0.12	−0.09	−0.07		−0.06	−0.13			

Madison, Wis.

Mar. 3	1.32		0.90	1.06							1.12
Mar. 4	2.26			1.03	1.33	1.60	1.30				3.63
Mar. 5	2.36		0.98	1.12	1.33	1.59	1.30				2.26
Mar. 7	3.00			0.76							3.81
Mar. 8	2.06			1.12	1.35	1.60	1.36				2.16
Mar. 12	3.00						1.17				3.30
Mar. 13	2.49						1.34				2.16
Mar. 14	2.62						1.41				2.26
Mar. 19	3.15		0.98	1.12	1.27	1.47					3.81
Mar. 20	3.99		0.70	0.89	1.06						2.74
Mar. 21	1.07			1.16	1.33	1.55					0.71
Mar. 24	4.17			0.90	1.21						3.81
Means			0.89	1.02	1.27	1.56	1.26				
Departures			−0.14	−0.14	−0.04		−0.03				

Lincoln, Nebr.

Mar. 2	1.02					1.57	1.37	1.20	1.05	0.88	1.32
Mar. 4	1.60			1.03	1.23	1.55	1.27	1.10	0.96	0.86	1.88
Mar. 5	2.36	0.86	1.02	1.08	1.17		1.29	1.06	0.87	0.65	2.16
Mar. 12	3.15						1.15	0.99	0.82	0.72	3.45
Mar. 13	4.17	0.73	0.83	0.98	1.17		1.07	0.86	0.72	0.57	3.15
Mar. 15	6.50	0.45	0.59	0.74	0.93						8.48
Mar. 19	3.15				1.27		1.29	1.17	0.99	0.90	4.37
Mar. 28	2.16			1.13	1.33	1.55	1.29	1.14	0.99	0.91	2.62
Mar. 29	2.62					1.55	1.33	1.18	1.04	0.91	3.30
Means		0.68	0.81	0.99	1.18	1.56	1.26	1.09	0.93	0.80	
Departures		−0.15	−0.13	−0.10	−0.09		−0.02	±0.00	−0.01	−0.01	

[1] Extrapolated.

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. C. S. Freeman, Superintendent U. S. Naval Observatory Data furnished by Naval Observatory in cooperation with Harvard, Yerkes, Mount Wilson, and Perkins observatories. The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column]

Date	Eastern standard civil time	Heliographic: Diff. long.	Heliographic: Longitude	Heliographic: Latitude	Area: Spot	Area: Group	Total area for each day
1930	h m	°	°	°			
Mar. 1 (Mount Wilson)	12 30	−71.0	4.0	−14.0		579	
		+9.0	84.0	−5.0		180	759
Mar. 2 (Naval Observatory).	12 7	−65.0	357.0	−15.5		664	
		+22.5	84.5	−5.5	123		787
Mar. 3 (Naval Observatory).	11 21	−52.0	357.3	−17.5		880	
		+35.5	84.8	−6.0	108		988
Mar. 4 (Naval Observatory).	11 20	−39.0	357.1	−17.0		1,034	
		+49.0	85.1	−6.0	77		1,111
Mar. 5 (Naval Observatory).	11 15	−26.0	357.0	−17.5		895	
		+62.5	85.5	−6.5	108		1,003
Mar. 6 (Naval Observatory).	11 25	−12.0	357.7	−17.0		864	
		+76.0	85.7	−6.5	93		957
Mar. 7 (Mount Wilson)	12 30	−24.0	331.9	+22.0		6	
		−3.0	352.9	−19.0		218	
		+9.0	4.9	−17.0		558	782
Mar. 8 (Naval Observatory).	14 23	−9.0	332.7	+20.5		12	
		+14.5	356.2	−17.0		679	691
Mar. 9 (Naval Observatory).	11 28	+26.0	356.1	−16.5		586	586
Mar. 10 (Naval Observatory).	12 7	−78.0	238.6	+9.5	9		
		+41.0	357.6	−16.5		509	518
Mar. 11 (Naval Observatory).	15 56	−64.5	236.8	+9.0		46	
		+59.0	0.3	−16.0		494	540
Mar. 12 (Naval Observatory).	10 56	−53.5	237.4	+9.5		31	
		+70.0	0.9	−16.0		370	401
Mar. 13 (Naval Observatory).	11 10	−63.0	214.6	+15.5		185	
		−42.0	235.6	+9.5	12		
		+84.0	1.6	−16.0		386	583
Mar. 14 (Naval Observatory).	10 51	−50.0	214.6	+16.0		93	
		−31.5	233.1	+11.0		22	
		−24.5	240.1	−10.5	3		118
Mar. 15 (Naval Observatory).	11 17	−35.0	216.2	+16.5		31	
		−23.0	228.2	+23.5		31	
		−17.5	233.7	+10.0		31	93
Mar. 16 (Naval Observatory).	10 58	−32.0	206.2	−7.5		6	
		−19.0	219.2	+16.5		31	
		−10.0	228.2	+24.0		31	
		−6.5	231.7	+11.5		370	438
Mar. 17 (Naval Observatory).	11 6	−35.5	189.4	+7.0	15		
		−15.0	209.9	−0.5		62	
		−5.5	219.4	+16.5		19	
		+2.5	227.4	+22.5	6		
		+8.0	232.9	+11.5		494	596
Mar. 18 (Naval Observatory).	11 2	−21.5	190.3	+7.5	12		
		−1.5	210.3	−1.0		93	
		+8.5	220.3	+16.5	3		
		+20.0	231.8	+12.0		370	478
Mar. 19 (Naval Observatory).	11 8	−7.5	191.0	+7.5	12		
		+12.5	211.0	−1.0		93	
		+34.5	233.0	+11.5		340	445
Mar. 20 (Naval Observatory).	11 9	−78.0	107.3	+6.0	62		
		+6.0	191.3	+7.5	9		
		+26.5	211.8	−1.0		77	
		+48.0	233.3	+11.5		216	364
Mar. 21 (Naval Observatory).	11 0	−65.0	107.2	+6.5	12		
		+19.5	191.7	+7.5	3		
		+42.0	214.2	0.0	15		
		+61.5	233.7	+11.5		185	215
Mar. 22 (Naval Observatory).	13 44	−73.5	84.0	+11.0	123		
		−50.0	107.5	+6.0	9		
		+39.5	197.0	+8.5		12	
		+57.0	214.5	0.0	31		
		+80.5	238.0	+10.0	123		298
Mar. 23 (Naval Observatory).	10 58	−61.0	84.9	+11.0	123		
		−31.5	114.4	+2.0		15	
		+20.0	165.9	−5.0	15		
		+69.0	214.9	0.0	6		159
Mar. 24 (Naval Observatory).	11 1	−73.0	59.7	+10.0	77		
		−48.0	84.7	+11.0	123		
		−18.0	114.7	+2.0		15	215
Mar. 25 (Naval Observatory).	12 41	−58.5	60.1	+9.5	62		
		−34.0	84.6	+10.5	108		170

POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	Eastern standard civil time	Heliographic			Area		Total area for each day
		Diff. long.	Longitude	Latitude	Spot	Group	
	h m	°	°	°			
Mar. 26 (Naval Observatory).	11 47	−80.5	25.4	−4.0	216		
		−45.5	60.4	+9.5	31		
		−32.0	73.9	+8.5		6	
		−21.0	84.9	+10.5	93		346
Mar. 27 (Naval Observatory).	11 1	−68.5	24.6	−3.0		340	
		−32.5	60.6	+10.5	31		
		−8.0	85.1	+10.5	62		433
Mar. 28 (Naval Observatory).	11 15	−55.0	24.8	−3.5		340	
		−19.5	60.3	+16.0	34		
		−5.0	74.8	+9.0		6	
		+5.0	84.8	+10.0		34	414
Mar. 29 (Naval Observatory).	11 4	−41.0	25.7	−4.0	293		
		−7.0	59.7	−17.5		49	
		−6.0	60.7	+9.0		37	
		+18.5	85.2	+10.0	25		404
Mar. 30 (Naval Observatory).	11 19	−30.0	23.4	−5.0		386	
		+7.0	60.4	−18.0		62	
		+9.0	62.4	+9.5		34	
		+31.5	84.9	+10.0	12		494
Mar. 31 (Naval Observatory).	11 7	−17.0	23.3	−5.0		509	
		+21.0	61.3	−16.5		43	
		+23.5	63.8	+9.5		56	608
Mean daily area for March							516

PROVISIONAL SUN-SPOT RELATIVE NUMBERS FOR MARCH, 1930 [1]

[Data furnished through the courtesy of Prof. W. Brunner, University of Zurich, Switzerland]

March, 1930	Relative numbers	March, 1930	Relative numbers	March, 1930	Relative numbers
1	a 23	11	17	21	37
2	24	12	30	22	d
3	28	13	26	23	7
4	54	14	17	24	23
5	55	15	Ec 28	25	17
6	50	16	Mc 44	26	d
7	b 50	17	b 49	27	36
8	b 49	18	a 44	28	a 31
9	53	19		29	30
10	28	20	32	30	Mc 52
				31	52

Mean, 28 days=35.0.

[1] Dependent alone on observations at Zurich and its station at Arosa.
a=Passage of an average-sized group through the central meridian.
b=Passage of a large group through the central meridian.
c=New formation of a large or average-sized center of activity: E, on the eastern part of the sun's disk; W, on the western part; M, in the central zone.
d=Entrance of a large or average-sized center of activity on the east limb.

AEROLOGICAL OBSERVATIONS

By RICHMOND T. ZOCH

Except for the levels close to the surface at Ellendale, free-air temperatures were below normal at all levels at all of the aerological stations.

Relative humidity departures were positive in the upper levels at Due West and Groesbeck and in the lower levels at Royal Center. Elsewhere they were negative.

Free-air vapor pressures were mostly below normal.

The resultant winds were variable at the 500 and 1,000 meter levels. At the 1,500 to 3,000 meter levels they were northwesterly throughout the northern and eastern part of the country. Above the 4,000-meter level they were northwesterly over the entire country.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during March, 1930*

TEMPERATURE (° C.)

Altitude (meters) m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	7.7	−2.3	8.5	−3.2	−1.4	+0.6	12.0	−1.3	1.4	−2.9
500	6.6	−1.7	7.0	−2.8	−1.9	+0.3	10.5	−1.1	0.1	−2.0
1,000	4.8	−1.5	4.1	−3.1	−4.0	−0.5	8.8	−1.3	−2.2	−2.4
1,500	3.1	−1.7	1.6	−3.2	−5.9	−1.3	7.0	−1.8	−4.2	−3.0
2,000	0.5	−2.5	−1.1	−3.6	−8.0	−1.6	5.3	−2.0	−5.9	−3.0
2,500	−2.3	−3.0	−3.5	−3.7	−10.6	−1.8	3.1	−2.0	−7.9	−2.7
3,000	−5.2	−3.4	−5.3	−3.4	−12.7	−1.1	0.7	−1.8	−10.3	−2.7
4,000	−10.0	−2.9	−9.1	−2.3	−18.5	−1.5	−4.5	−1.2	−15.2	−2.6
5,000	−16.8	−2.9	−14.4	−1.5	−25.3	−2.4			−22.3	−3.5

RELATIVE HUMIDITY (%)

Surface	58	−6	63	−1	66	−7	71	0	74	+3
500	57	−5	60	−2	66	−6	66	−1	71	+1
1,000	54	−5	59	−2	60	−4	62	+2	68	+4
1,500	47	−5	58	−2	55	−3	55	+4	59	+2
2,000	44	−2	57	+1	50	−6	48	+5	51	−3
2,500	41	−1	54	+3	50	−6	47	+8	46	−6
3,000	40	0	50	+6	47	−10	49	+12	48	−4
4,000	35	−2	46	+5	48	−5	50	+12	39	−10
5,000	25	−2	54	+7	47	−6			39	−15

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during March, 1930*—Continued

VAPOR PRESSURE (*mb.*)

Altitude (meters) m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	6.49	−1.73	7.48	−1.87	3.71	−0.23	10.25	−1.32	5.13	−1.21
500	6.03	−1.19	6.52	−1.66	3.59	−0.24	8.87	−1.07	4.57	−0.84
1,000	4.95	−0.98	5.32	−1.50	2.72	−0.30	7.28	−0.74	3.76	−0.59
1,500	3.82	−0.95	4.33	−1.24	2.15	−0.40	5.79	−0.30	2.80	−0.71
2,000	2.91	−0.79	3.56	−0.80	1.69	−0.46	4.62	+0.22	2.16	−0.80
2,500	2.06	−0.88	2.66	−0.64	1.34	−0.44	3.92	+0.52	1.60	−0.86
3,000	1.69	−0.68	2.02	−0.27	1.05	−0.39	3.40	+0.70	1.43	−0.70
4,000	1.10	−0.36	1.51	+0.17	0.71	−0.16	1.63	−0.23	0.81	−0.56
5,000	0.98	−0.36	1.42	+0.30	0.33	−0.23			0.59	−0.47

TABLE 2.—*Free-air data determined at Naval air stations during March, 1930*

Altitude (meters) m. s. l.	Temperature (°C.)			Relative humidity (%)		
	Pensacola, Fla.	San Diego, Calif.	Washington, D. C.	Pensacola, Fla.	San Diego, Calif.	Washington, D. C.
Surface	9.6	16.4	4.4	73	64	64
500	8.6	15.4	3.4	59	59	56
1,000	6.3	13.9	1.2	46	51	55
2,000	1.6	7.9	−4.1	41	42	58
3,000	−1.3	1.3	−7.9	32	34	46
4,000						
5,000						

TABLE 3.—*Free-air resultant winds (meters per second) based on pilot balloon observations made near 7 a. m. (E. S. T.) during March, 1930*

Altitude (meters) m. s. l.	Broken Arrow, Okla. (233 meters)		Burlington, Vt. (132 meters)		Cheyenne, Wyo. (1,868 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Havre, Mont. (762 meters)		Jacksonville, Fla. (65 meters)		Key West, Fla. (11 meters)		Los Angeles, Calif. (40 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°	
Surface	N 63 W	1.5	S 55 W	1.2	N 71 W	4.8	S 81 W	1.9	N 40 W	3.2	S 29 W	0.9	S 80 W	1.3	N 63 W	1.6	S 66 E	1.1	N 71 W	1.0
500	S 89 W	2.5	S 71 W	4.6			N 88 W	5.9	N 44 W	3.8	S 60 W	2.2			N 61 W	4.0	S 28 E	2.3	S 83 E	1.9
1,000	N 80 W	5.6	S 87 W	6.3			N 87 W	6.8	N 44 W	6.8	N 76 W	3.9	S 78 W	4.3	N 79 W	7.1	S 12 W	3.3	E	3.0
1,500	N 61 W	6.1	N 74 W	9.6			N 79 W	8.1	N 39 W	8.8	N 57 W	6.1	N 81 W	7.6	S 86 W	9.2	S 42 W	5.6	N 75 E	2.5
2,000	N 60 W	7.0	N 68 W	11.3	N 70 W	7.7	N 77 W	10.0	N 41 W	9.4	N 64 W	7.8	N 63 W	7.9	S 88 W	11.7	S 65 W	7.0	N 56 E	2.1
2,500	N 58 W	9.2	N 70 W	14.4	N 56 W	12.0	N 81 W	10.4	N 41 W	11.0	N 64 W	8.2	N 61 W	8.2	S 84 W	14.1	S 67 W	8.4	N 42 E	2.5
3,000	N 56 W	10.6	N 78 W	14.5	N 51 W	11.6	N 77 W	11.8	N 40 W	9.2	N 72 W	9.8	N 56 W	9.3	S 82 W	17.8	S 81 W	8.4	N 13 E	1.2
4,000	N 72 W	9.1	S 87 W	12.8	N 50 W	6.9	N 87 W	18.5	N 40 W	12.8			N 33 W	7.8			N 83 W	11.4	N 17 W	3.2
5,000							N 88 W	18.6	N 30 W	9.4							N 74 W	11.6		

Altitude (meters) m. s. l.	Medford, Oreg. (446 meters)		Memphis, Tenn. (145 meters)		New Orleans,[2] La. (25 meters)		Omaha, Nebr. (313 meters)		Royal Center, Ind. (225 meters)		Salt Lake City, Utah (1,280 meters)		San Francisco, Calif. (60 meters)		Sault Ste. Marie, Mich. (198 meters)		Seattle, Wash. (14 meters)		Washington, D. C. (5 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°	
Surface	S 26 E	0.5	S 72 W	2.0	N 11 E	1.0	N 36 W	1.8	N 88 W	1.5	S 20 E	1.1	S 59 E	1.3	N 20 W	0.8	S 63 E	0.9	N 85 W	2.0
500	S 38 W	0.4	N 86 W	6.6	N 41 W	4.0	N 47 W	3.8	N 87 W	5.5			N 19 W	0.9	N 11 W	2.2	N 67 W	1.2	S 88 W	6.7
1,000	S 4 E	0.6	N 72 W	8.4	N 43 W	6.0	N 51 W	7.8	N 73 W	6.5			N 19 E	3.0	N 33 W	5.8	N 22 W	1.4	N 85 W	8.1
1,500	N 83 E	0.5	N 67 W	9.9	N 57 W	7.3	N 45 W	7.9	N 76 W	9.1	S 3 E	1.8	N 19 E	2.7	N 39 W	7.3	N 49 W	1.0	N 81 W	10.5
2,000	N 24 W	1.2	N 59 W	11.5	N 75 W	8.5	N 41 W	9.2	N 79 W	11.1	S 70 W	1.8	N 26 E	3.9	N 28 W	6.4	N 36 W	1.0	N 80 W	10.7
2,500	N 29 W	3.2	N 54 W	11.7	N 81 W	11.8	N 49 W	11.4	N 76 W	13.8	N 88 W	3.4	N 35 E	1.8	N 30 W	5.6	N 13 W	2.0	N 84 W	11.0
3,000	N 23 W	4.7	N 67 W	9.3	N 82 W	11.6	N 52 W	11.1	N 79 W	13.7	N 69 W	5.1	N 44 W	1.4	N 29 W	8.2	N 29 W	2.0	S 77 W	12.5
4,000	N 25 W	9.6					N 52 W	8.8	N 74 W	15.9	N 59 W	5.8								

TABLE 4.—*Observations by means of kites, captive and limited-height sounding balloons during March, 1930*

	Broken Arrow, Okla.	Due West, S. C.	Ellendale, N. Dak.	Groesbeck, Tex.	Royal Center, Ind.
Mean altitudes (meters) m. s. l., reached during month	3,133	2,644	3,207	2,946	3,092
Maximum altitude (meters) m. s. l., reached and date	[1] 5,031	[2] 5,369	[3] 5,385	[4] 4,485	[1] 5,924
Number of flights made	35	37	36	32	32
Number of days on which flights were made	31	29	31	26	31

[1] 9th. [2] 31st. [3] 19th. [4] 17th.

In addition to the above there were approximately 125 pilot balloon observations made daily at 53 Weather Bureau stations in the United States.

WEATHER IN THE UNITED STATES

THE WEATHER ELEMENTS

By M. C. BENNETT

GENERAL SUMMARY

The weather for March, 1930, was warm for the season during the first half, but the latter half in many portions was decidedly cold; and while March is normally much warmer than February, this year the month, as a whole, in many interior and southern sections was actually colder than February, which had been abnormally warm.

The precipitation for the month was unevenly distributed. From two to more than four times the normal was received in portions of the Southeast, while more than normal amounts fell in portions of Texas, the far Southwest, and the northeast section; but only scanty falls were received in most interior valley sections, the northern Great Plains, the mid-West, and the Pacific Northwest.

PRESSURE AND WINDS

At the beginning of the month a low-pressure area was central over the upper Lake region, accompanied by moderate precipitation throughout that region, and also over the northern portion of the Mississippi Valley, the same being largely in the form of snow. Light rain also prevailed over much of the South Atlantic and portions of the east Gulf States. During the next few days these precipitation areas moved off the northeast coast, and were followed by generally fair and moderately cool weather over most of the country, except in portions of the central and southern Pacific coast areas, where rain occurred almost daily.

On the 6th a rather extensive low-pressure area extended over the Great Plains region from western Texas to the northern border States, and precipitation prevailed over most sections to the westward of the Rocky Mountains and from the lower Lakes northeastward. By the next day this storm had moved to the southern Ohio Valley, and widespread precipitation prevailed from the central Mississippi Valley southward, also to the Atlantic, and was accompanied by heavy thunderstorms in many localities. Light precipitation prevailed also over much of the region from the northern portions of New Mexico and Arizona to the northern border States, and likewise in the western portion of Washington. During the next

two days this eastern storm moved off the northeast coast, causing widespread precipitation throughout the East and frequent thunderstorms and heavy rainfalls.

On the 10th a low-pressure area extended from the upper Lake region southwestward to western Texas, and on the 11th was central over the Great Lakes, accompanied by light precipitation throughout the Lake region and southward, east of the Mississippi River, to the Gulf; and during the next day this area moved out the St. Lawrence Valley, with light precipitation prevailing throughout most of the Eastern States.

About the middle of the month high pressure prevailed over most northern and central areas east of the Rocky Mountains, and was accompanied by generally fair weather, but light rain fell throughout much of the South, the extreme northern Rocky Mountain region and the South Pacific area, and during the next several days moderate to light precipitation prevailed over most sections of the country. By the 19th precipitation overspread much of the East with some heavy falls in the South and Southeast. On the 20th and 21st much colder weather moved in from the Northwest, and during the next several days a series of low-pressure areas developed in the West and Southwest and moved easterly and northeasterly, accompanied by precipitation over much of the eastern half of the country, the falls being moderately heavy in many sections.

On the 28th a precipitation area overspread much of the southern half of the Gulf States and moved easterly, then northeasterly along the Atlantic coast, and was accompanied by heavy rain in some localities near the coast. The month closed with generally high pressure and fair weather throughout the East, but relatively low pressure in the upper Lake region and the southern plateau and South Pacific regions, though with light precipitation in only a few localities.

The month was noted as rather windy at many stations, as is usual during March; but except for the moderate tornadoes that visited portions of the Gulf States on the 6th there were few storms of sufficient intensity to cause damaging winds over extensive areas, and wind damage was rather infrequent, as shown by the comparatively few instances recorded in the table at the end of this section.

The distribution of the monthly means of pressure is graphically shown in Chart VI, while the departures from the normal and changes from the preceding month are likewise shown in the insets of Charts II and III.

TEMPERATURE

The warm weather that prevailed during much of February continued quite generally during the first half of March, but from about the 18th onward to the end of the month temperature lower than normal for the latter part of March was the rule. As a whole, the month was cool in the South and in the Ohio Valley, but moderately warm in most of the North and practically all of the far West.

The first decade was mainly warmer than normal, especially in the north-central and northeastern portions, but was somewhat cooler than normal in the south-central and southeastern districts, while beginning cold in the Rocky Mountain and Plains regions where warmth soon replaced the cold weather.

The week from the 11th to the 18th was decidedly warm, as a whole, especially in the central valleys, the upper Mississippi Valley, and most of the Missouri Valley, but was slightly cooler than normal along the Gulf coast and in most parts of the Pacific States.

About the 19th there was reaction to colder weather in the Great Plains, and low temperatures soon overspread most central portions of the country, reaching the Eastern States only about the 22d. To eastward of the Mississippi River the freezing weather did not extend farther south than the lower Ohio Valley and western North Carolina, but considerable portions of the Southwest reported temperatures many degrees below freezing.

The closing fortnight was generally cooler than normal, notably in the Mississippi Valley and the Lake region and from the southern Rocky Mountain region eastward to the South Atlantic coast. In the middle Rocky Mountain region and the middle and northern Plains the weather was mainly warm from the 21st to the 25th, but cold after the 25th. To westward of the Divide and in some Atlantic coast districts north of Chesapeake Bay this fortnight was warmer than normal, the districts from central California to Puget Sound having especially mild weather after the 24th.

The month averaged warmer than normal along the Canadian border, also near the middle Atlantic coast, in the upper Mississippi and middle and upper Missouri Valleys, in nearly all parts of the Plateau region, and especially in the Pacific States. The month was decidedly cooler than normal in all States that touch the Gulf of Mexico, and the tendency to temperatures below normal prevailed as far north as the interior of Maryland, the Ohio Valley, Missouri, Kansas, and southern Wyoming, also as far as the lower Colorado River.

The highest temperatures were usually recorded about the middle of the month from the Plains States eastward, though at scattered dates in the Gulf States, while in the far West and the southern Rocky Mountain region they usually occurred during the last week. Practically throughout the country they were many degrees below the highest marks of March in previous years, and this was particularly the case to eastward of the Mississippi River. The highest temperature reported was 104° in southern Texas on the 6th.

The lowest marks occurred generally during the first five days, but in the southern Rocky Mountain region they occurred about the 28th. They were almost invariably well within the limits shown by other years. The lowest reported was −31° at an elevated station in Colorado, but points in Wyoming and Montana reported −30°.

PRECIPITATION

During the first few days of the month rather widespread precipitation prevailed in much of the East and in the Lake region; however, the falls were moderate to light, except in a few localities in the Southeast, where thunderstorms occurred. During the latter half of the first decade heavy precipitation was received at many stations in the South from eastern Mississippi eastward and throughout the Atlantic Coast States, also some heavy falls were received at this time in central and northern California.

During the early part of the second decade generous to heavy precipitation was received in the Southeast and along the Gulf, and again during the latter part of this decade moderately heavy rain fell from Tennessee southward to the Gulf and over most of the Florida Peninsula. Some heavy falls also occurred in Arizona and California and other portions of the far Southwest, while moderate amounts were received in the Ohio Valley and throughout much of the Atlantic area.

Precipitation was general throughout much of the East during the greater part of the third decade, the falls being fairly heavy in portions of the Southeast during the early part of the decade, while toward the latter part moderately heavy rain fell in the west Gulf States and along the South Atlantic coast, and excessive amounts were received in much of the Florida Peninsula. Tampa, Fla., reported a fall of 5.62 inches for the 24 hours ending at 8 a. m. of the 29th. Moderate to generous amounts were received in the Northeast and portions of the Lake region and far Southwest, also the early portion of the decade saw considerable rain in the North Pacific region.

As a whole, the month was one of deficient precipitation. The shortage was especially marked, and was particularly unfortunate because of previous scarcity of moisture, in the middle Plains. Most of the middle Plateau and the North Pacific States, Oregon, especially, had notable shortages; likewise North Dakota, with eastern Montana and northern Minnesota.

There was mainly less precipitation than normal in the Missouri Valley, and less in all but a few small portions of the Mississippi and Ohio Valleys and the upper Lake region. Another region of shortage extended from the northern portions of Georgia and South Carolina to southern New England.

More than normal precipitation was received in the lower Lake region, northern New York, and most of New England; likewise in many portions of the Southeast, especially in central and northeastern Florida.

West of the Mississippi River there was more precipitation than normal in large portions of Montana, Idaho, and Wyoming, some parts of Texas and New Mexico, and most of Arizona and southern and central California.

The greatest amount so far reported, 12.88 inches, was noted at two stations, very far apart, one being in central Florida and the other in western Washington.

SNOWFALL

The snowfall was mainly less than the average amounts of previous March records. In those regions where moderate to considerable quantities are likely to occur the shortage was especially marked in those portions of the Middle Atlantic States lying to eastward of the Appalachian Divide, and in Minnesota, most of Iowa and the Dakotas, and the middle Plains.

More snow than usual was received from northeastern Missouri eastward and northeastward over much of the Ohio Valley, especially the northern and eastern parts, and over the lower and the southern portion of the upper Lake region. In these areas, especially near Lake Michigan, the most notable snowstorm of the month was particularly felt; this occurred about the 24th to 27th and was accompanied by high winds, resulting in serious drifting and great delay to traffic.

In the higher portions of the West the snowfall exceeded the normal in much of Montana, and in large portions of New Mexico, Arizona, and southern California; yet in these last-named States the normal amounts of March are not especially large. In the mountainous portions of the States of the Pacific Northwest the March snowfall was especially scanty.

The stored supply of snow in the high mountains of the West was mainly of disappointing quantity at the end of March. The districts with best prospects for a good summer flow were chiefly in the Rocky Mountains from northern Colorado northward.

RELATIVE HUMIDITY AND CLOUDINESS

The average relative humidity for the month was generally below the normal over most districts, except in some of the higher elevations of the Rocky Mountains, the northern portions of the Lake region, and extreme southern Florida, where the average humidity was mainly above the normal.

In much of the Gulf States, the upper Lake region, and the northern Rocky Mountain area, cloudy weather seems to have been more prevalent than usual, while in many of the central areas more clear weather than usual in March was noted.

SEVERE LOCAL STORMS, MARCH, 1930

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path yards [1]	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Skene, Miss.	6	4:30 p. m.	267	2	$20,000	Tornado	A number of residences and other small buildings demolished; 12 persons injured.	Official, U. S. Weather Bureau.
Kosciusko, Miss. (5 miles north of).	6	P. m.		1		do	A house and barn wrecked; 2 autos damaged; 2 persons injured.	Do.
Gregory, Ark.	6	P. m.			30,000	do	A number of buildings demolished; 5 persons injured.	Do.
Homer, La. (10 miles southwest of).	6	7:30 p. m.	300	1	10,000	do	Several homes demolished; path 8 miles long.	Do.
Robeline, La. (3 miles west of).	6	9:30 p. m.			5,600	Tornadic wind	Buildings and timber damaged over path 1 mile long.	Do.
Seman, Ala.	7	2 a. m.			4,500	Tornado	Some property damage.	Do.
Bellview, N. Mex.	14	3:15 p. m.	5 mi.			Hail	Small damage; too early for crops.	Do.
San Diego, Calif.	15	8 p. m.				Hail and wind	Some damage to tender plants and trees.	Do.
Webster County, Iowa.	16	8 p. m.			3,500	Tornado	Damage chiefly to buildings.	Do.
Harlan, Iowa.	16					Heavy hail	Much glass in greenhouses broken.	Do.
Arthur City, Tex.	18	4 a. m.				Wind	A house demolished, another moved from foundation, and several unroofed; 1 person injured.	Do.
Kossuth, Miss.	18					do	Considerable damage to dwellings and outbuildings.	Do.
Tennessee (central and eastern counties).	18			1	30,000	Destructive wind	Dwellings, churches, schools, timber, etc., damaged; 8 or 10 persons injured.	Do.
Montana (western), Idaho (northern), and Washington (eastern).	19	P. m.				do	Telephone and power lines damaged; trees uprooted; steel grain storage tank wrecked; several persons injured.	Great Falls (Montana) Tribune.
Headland, Ala.	19	9 p. m.			10,000	Tornado	Considerable damage to property; 1 person seriously injured.	Official, U. S. Weather Bureau.
Wisconsin and Michigan (southern) and northern Illinois and Indiana.	25–26					Heavy snow and wind.	Worst storm in history in some places; transportation of all kinds discontinued or delayed; schools closed.	Do.

[1] Mi. signifies miles instead of yards.

RIVERS AND FLOODS

By R. E. SPENCER

Except for moderate losses resulting from the rises in the Alabama and Tombigbee systems, floods during March were without important consequence.

In his discussion of the flood in the Tombigbee system, the official in charge of the Weather Bureau office at Mobile, Ala., refers to the unusual rapidity of the rise in the Black Warrior River at Tuscaloosa, Ala.:

The stage at this station at 8 a. m. on March 6 was 12.3 feet, and at the same hour on March 7 it was 48.1 feet—a 24-hour rise of 35.8 feet, which is unprecedented since the establishment of the station. It was ascertained from the river observer that the stage at 7 p. m. March 6 was about 13 feet, which makes a rise of approximately 35 feet in 13 hours.

Relative to the effects of this flood, Mr. Ashenberger's report continues:

Only the lowest river bottoms of the Tombigbee from near Demopolis to its confluence with the Alabama and of the Black Warrior from its mouth to some distance above Tuscaloosa were inundated. Reports from correspondents give the aggregate monetary value of property losses as follows:

Tangible property	$21,800
Matured crops	2,000
Prospective crops (5,000 acres)	50,000
Livestock and other movable property	1,900
Suspension of business	38,000

The aggregate of the monetary value of property saved by Weather Bureau warnings is $46,500.

The Alabama system flood, resulting from somewhat unevenly distributed rains on March 6–7 over the Coosa, upper Alabama, and tributary streams, did comparatively little damage:

Tangible property (largely roads)	$3,000
Matured crops	6,100
Prospective crops (700 acres, mostly corn)	4,000
Livestock	2,300
Suspension of business	16,100

A saving of $3,000 was reported through the use of Weather Bureau warnings, in addition to which a considerable unreported saving in livestock was effected.

A loss of about $2,500 was the result of an overflow of lowlands, caused by an ice gorge which formed on the night of March 5–6 in the Missouri River just below Vermilion, S. Dak., at the junction of the Vermilion and Missouri Rivers.

Continued high stages in the Illinois and Wabash Rivers were properly forecast and were attended by no material damage.

The Tallahatchie River flood, which still persists, will be reported upon when it subsides.

The usual table of crest stages follows:

[All dates in March unless otherwise specified]

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC DRAINAGE					
	Feet			Feet	
James: Columbia, Va	18	8	9	19.0	8
Roanoke: Randolph, Va	21	9	9	21.5	9
Santee:					
Rimini, S. C	12	(1)	5	13.3	Feb. 23
		11	16	12.6	13
		22	25	12.8	25
Ferguson, S. C	12	(1)	3	12.6	Feb. 24
		9	19	12.9	14
		23	27	12.4	25
Saluda: Pelzer, S. C	7	8	8	7.0	8
Altamaha: Everett City, Ga	10	20	(2)	10.4	24–25
Ocmulgee: Abbeville, Ga	11	15	16	11.3	15
EAST GULF DRAINAGE					
Alabama: Selma, Ala	35	11	13	35.8	12
Coosa:					
Gadsden, Ala	22	9	12	23.2	9
Lock No. 4, Lincoln, Ala	17	7	13	19.7	8
Etowah: Canton, Ga	11	7	8	18.2	7
Cahaba: Centerville, Ala	25	7	8	26.5	7
Tombigbee: Lock No. 4, Demopolis, Ala	39	9	19	40.7	15
Black Warrior: Lock No. 10, Tuscaloosa, Ala	46	7	10	58.5	8
West Pearl: Pearl River, La	13	6	8	13.4	7
GREAT LAKES DRAINAGE					
Saginaw: Saginaw, Mich	19	(1)	2	20.7	Feb. 27
Flint: Flint, Mich	11	(1)	1	12.8	Feb. 25
Grand:					
Eaton Rapids, Mich	5	(1)	2	5.4	Feb. 22
Grand Rapids, Mich	11	(1)	3	13.3	Feb. 28
MISSISSIPPI DRAINAGE					
Tuscarawas: Coshocton, Ohio	8	(1)	1	12.0	Feb. 27
Hocking: Athens, Ohio	17	9	9	17.5	9
Wabash:					
Covington, Ind	16	(1)	2	18.9	1
Terre Haute, Ind	16	(1)	2	16.4	1–2
Vincennes, Ind	14	2	6	14.8	5
Mt. Carmel, Ill	16	(1)	7	19.8	5
Tippecanoe, Norway, Ind	6	(1)	2	6.5	Feb. 24 and Mar. 2
White: Decker, Ind	18	4	5	18.3	4–5
White, West Fork:					
Elliston, Ind	19	(1)	2	22.1	Feb. 28
Edwardsport, Ind	15	(1)	4	17.8	2
Elk: Fayetteville, Tenn	14	7	9	18.0	7
Illinois:					
Peru, Ill	14	(1)	17	18.4	Feb. 27
Henry, Ill	10	(1)	13	12.6	2
Peoria, Ill	18	(1)	9	19.3	2–3
Havana, Ill	14	(1)	21	16.5	4–5
Beardstown, Ill	14	(1)	23	18.0	5–6
Pearl, Ill	12	(1)	16	14.4	6–7
Meramec:					
Pacific, Mo	11	(1)	(3)	14.9	Feb. 28
		9	10	12.3	9
Valley Park, Mo	14	(1)	1	15.6	Feb. 27
St. Francis:					
Fisk, Mo	20	(1)	1	22.5	Feb. 28
St. Francis, Ark	18	4	5	18.2	5
Missouri: Wolf Point, Mont	17	30	30	17.7	30
Yellowstone: Miles City, Mont	13	14	14	14.1	14
Arkansas: Yancopin, Ark	29	(1)	4	35.0	Jan. 27–30
Black: Corning, Ark	11	(1)	16	12.0	4–5
Tallahatchie: Swan Lake, Miss	25	(1)	(2)	31.9	Jan. 27–29

[1] Continued from last month. [2] Continued at end of month. [3] Below flood stage at 8 a. m., Mar. 1.

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, MARCH, 1930

By J. B. KINCER

General summary.—During the first decade the generally mild conditions, with much sunshine, in the central valleys and West, made a favorable period, although there were some unfavorably heavy rains in the Southeast; the additional moisture was beneficial in some parts of this section. Cold weather caused some harm to tender truck in east Gulf States, with considerable injury indicated in Florida. Winter grains continued to make satisfactory advance in the principal producing sections, except for too much moisture in parts of the Ohio Valley and continued dryness in the Southwest. Preparations for corn planting made good progress, with considerable put in throughout the Gulf section and seeding became well advanced in eastern Texas. Rains interfered with work in the eastern Cotton Belt, but much land had been prepared, while planting progressed in southern Texas and considerable cotton was up.

During the second decade weather conditions continued largely favorable for agricultural operations, although there was some delay by showers to field work in parts

of the Southeast; seasonal work was well up in general, with corn being planted as far north as southern Oklahoma and central Arkansas. Light to moderate rains were beneficial in Ohio Valley sections and local precipitation was received in the droughty Southwest, but over a considerable area moisture was badly needed. Some snow remained in the northern Spring-Wheat Belt, but considerable plowing and disking were accomplished in the south and a little spring wheat was sown in northwestern Iowa. Conditions were generally favorable in the Cotton Belt and much preparation of the soil for planting was done; seeding continued in Texas. Vegetation advanced rapidly during the week, and fruit trees were showing color northward to the lower Ohio Valley.

During the last decade cold weather retarded the growth of vegetation and slowed up farm work generally. The coolness was especially marked in the central valley States and the South, with considerable harm to tender vegetation and some damage to fruit bloom as far north as parts of the Ohio Valley. Precipitation was beneficial locally in the Southwest, but moisture was still needed over much of the area, especially in Oklahoma and adjoining States. Low temperatures and dry soil were unfavorable for winter wheat in this area, but snows were helpful in the Ohio Valley. Preparations for planting in the Corn Belt were largely inactive due to wetness, coolness, and frozen soil in the northern part, while in the more southern sections little work was done. Very little cotton was put in during the period; preparation of seed beds had been retarded, but this work was generally well up. Progress of cotton was poor in Texas and much seed lost, due to unfavorable weather for germination.

Small grains.—During the first decade there were still reports of unfavorable freezing and thawing in the Ohio Valley and condition of winter wheat varied widely there. Mostly satisfactory advance was made in the western portions of the belt, except that rain would have helped in Kansas and other parts of the Southwest. Favorable conditions continued in the South and East. Plowing and spring oat sowing had advanced to the Ohio Valley. During the second decade condition of winter wheat continued to vary widely in the Ohio Valley and but little change was noted in the more western parts of the belt; moisture was locally beneficial in Kansas, with but little damage noted from soil blowing. The general condition of the crop remained largely unchanged in most of the South, East, and Northwest. Plowing and disking for oats progressed northward to South Dakota, with oats put in as far north as southern Iowa and Nebraska and a little spring wheat seeded locally in Iowa and southern South Dakota. During the last decade winter wheat was benefited by snow in the western Ohio Valley and the crop was holding up well. In the central and southwestern parts of the belt precipitation was badly needed, with marked deterioration appearing in south-central and western Kansas. Winter cereal crops did well in the East, but in the Northwest a need of moisture was again apparent. Some oats were put in during the period, but spring wheat seeding was retarded by frozen ground in places. Oats made only slow growth in the Southeast and the soil was generally too dry and cold for proper germination of seed.

Miscellaneous crops.—Pastures and meadows greened up rapidly in the East during the first two decades, but the cold weather the latter part of the month generally stopped growth. In the great western grazing sections conditions were mostly favorable, with feeding light throughout and the range furnishing some feed. Generous to heavy rains in parts of the far Southwest were highly beneficial. Some slight shrinkage occurred toward the close of the month, but livestock were favored generally, with lambing proceeding satisfactorily.

There was some frost damage to tender varieties of truck during the first and last decades, especially in the Florida Peninsula early in the month, when local injury occurred south to the Miami district. Gardens and truck did well in most sections, however, with the warmth during the middle period especially favorable in helping overcome the effects of the frosts. Some slight injury to fruit trees and bloom was reported during the cold weather, but favorable retardation was reported from many parts.

WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

NORTH ATLANTIC OCEAN

By F. A. YOUNG

The most unusual feature of the weather over the North Atlantic during March was the unequal distribution of gales, as the number of days in which they occurred was very much below the normal over the northern section, and equal to or above over the southern. Up to time of writing gales have not been reported on more than 1 day in any 5° square north of the fiftieth parallel, while between the thirtieth and thirty-fifth parallels and twentieth to sixtieth meridians they occurred on from 2 to 6 days, the maximum being in the square immediately north of the Azores.

As shown in Table 1, the average monthly pressure at stations on the American coast north of Hatteras was considerably below normal, while on the British Isles the negative departures were comparatively small.

Fog was observed in different localities as follows: Over the Grand Banks, from 9 to 14 days; along the American coast between Hatteras and Nova Scotia, from 6 to 8 days; in the Gulf of Mexico, from 1 to 3 days; in the vicinity of the Azores, from 1 to 2 days; and on not more than 1 day in any 5° square east of the thirty-fifth meridian.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, 8 a. m. (seventy-fifth meridian). North Atlantic Ocean, March, 1930*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland	29.82	(1)	30.32	15th	29.36	11th.
Belle Isle, Newfoundland	29.66	−[2] 0.14	30.34	8th	28.84	21st.
Halifax, Nova Scotia	29.69	−[2] 0.27	30.36	1st	28.94	3d.
Nantucket	29.78	−[2] 0.24	30.34	15th	29.28	19th.
Hatteras	29.92	−[2] 0.18	30.32	15th	29.24	8th.
Key West	29.99	−[2] 0.09	30.18	27th [4]	29.76	8th.
New Orleans	30.04	−[2] 0.05	30.44	3d	29.52	7th.
Cape Gracias, Nicaragua	29.92	−[2] 0.06	29.98	1st [4]	29.82	7th.[4]
Turks Island	30.07	+[2] 0.05	30.24	1st	29.96	16th.
Bermuda	29.99	−[2] 0.15	30.24	1st	29.70	9th.
Horta, Azores	30.04	−[2] 0.08	30.58	11th	29.46	20th.
Lerwick, Shetland Islands	29.67	−[2] 0.03	30.50	1st	29.06	29th.
Valencia, Ireland	29.82	−[2] 0.08	30.50	1st	29.08	15th.
London	29.87	−[3] 0.09	30.50	5th	29.17	16th.

[1] No normal available.
[2] From normals shown on Hydrographic Office Pilot Charts, based on observations at Greenwich mean noon, or 7 a. m., seventy-fifth meridian time.
[3] From normals based on 8 a. m. observations.
[4] And on other date or dates.

Charts VIII to XI cover the period from the 1st to 4th, inclusive, when heavy weather prevailed over the middle and western sections of the ocean.

On the 5th a severe disturbance was central about 400 miles south of the Azores, with a secondary LOW about the same distance south of St. Johns, Newfoundland, while anticyclonic conditions prevailed over the British Isles.

On the 6th and 7th a depression, that on the latter date was central in western Kentucky, extended as far south as the Gulf of Mexico, with barometric readings on the 7th of 29.52 inches at both New Orleans and Pensacola. On the 8th New York, with a reading of 29.08 inches, was near the center of this LOW, and on that day as well as the 9th westerly gales prevailed along the American coast, between the twenty-fifth and fortieth parallels.

From the 10th to 12th the Azores HIGH and Icelandic LOW were both well developed, and during that period northerly to westerly gales occurred between the twenty-fifth meridian and European coast.

From the 13th to 15th a LOW was over the western section of the ocean that reached its greatest intensity on the 14th, with westerly winds of force 7 to 9 between the thirty-fifth and fortieth parallels and fiftieth to sixtieth meridians; on the 15th northerly gales also occurred over the steamer lanes between the twentieth and thirtieth meridians.

On the 18th and 19th, the central section of the ocean was covered by a disturbance that on the former date extended from the thirtieth to forty-fifth parallels. On the 20th the center of this LOW was about 300 miles north of the Azores, where strong westerly gales prevailed.

On the 22d Belle Isle, Newfoundland, was near the center of a deep LOW, with westerly winds of force 7 to 9 between the fortieth and forty-fifth parallels. From the 23d to 25th moderate weather was the rule over the ocean as a whole, although a few vessels reported winds of force 7 and 8 during this period.

On the 26th and 27th a depression was over Maine and the Province of Quebec, with resultant westerly gales along the coast from Hatteras to Nantucket. On the 26th there was also a LOW central near 50° N., 35° W. that moved slowly eastward, and on the 28th was off the coast of Ireland, the storm area then extending from the forth-fifth to fifty-fifth parallels, and tenth to twenty-fifth meridians.

A depression that on the 29th was central near 50° N., 40° W., developed later into the most severe disturbance of the month, and on the 30th the steamer lanes east of the fifty-fifth meridian were swept by moderate to strong westerly gales. By the 31st the disturbance had contracted somewhat in extent but increased in intensity, as vessels between the Azores and fiftieth parallel on that date, encountered winds of hurricane force, as shown by reports in storm table.

OCEAN GALES AND STORMS, MARCH, 1930

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	° ′				*Inches*					
Mercer, Am. S. S.	Liverpool	Boston	45 55 N	39 05 W	Mar. 1	—, 1	Mar. 2	29.65	NNW	NNW, 7	NNW	NNW, 10	Steady.
Calgarolite, Br. M. S.	Lobitos, Peru	Halifax	36 36 N	66 41 W	Mar. 2	8 a, 2	Mar. 3	29.43	S	SSW, 8	NW	NW, 9	SW-W-NW.
Tomalva, Am. S. S.	Rotterdam	Boston	46 20 N	40 38 W	do	1 a, 2	Mar. 2	29.80	NNW	NNW, 9	N	NNW, 10	NNW-N.
Julius Schindler, Ger. M. S.	Curacao	Hamburg	43 14 N	26 16 W	Mar. 1	Noon, 2	do	29.41	SSE	S, —	WSW	—, 10	S-WSW.
Texan, Am. S. S.	Philadelphia	Boston	41 42 N	69 45 W	Mar. 2	7 a, 3	Mar. 3	29.21	NW	WNW, 10	NW	WNW, 10	NW-WNW.
Kentuckian, Am. S. S.	Canal Zone	New York	29 41 N	74 40 W	Mar. 3	2 p, 3	Mar. 4	29.79	NW	NW, 9	NW	NW, 9	WNW-NNW.
Ossining, Am. S. S.	Algiers	Baltimore	34 32 N	52 57 W	do	4 a, 4	do	29.56	SW	W, 10	W	W, 10	SW-W.
Grete, Ger. S. S.	Hamburg	Savannah	40 00 N	24 00 W	Mar. 4	4 p, 4	Mar. 6	29.61	Var	ESE, 6	NNW	NNE, 10	E-N-NNW.
Darian, Br. S. S.	Liverpool	Boston	42 09 N	45 54 W	Mar. 5	8 a, 5	do	29.83	WSW	WSW, —	NW	—, 10	WSW-W-NW.
St. Joseph, Fr. S. S.	Bordeaux	Pointe-a-Pitre	32 45 N	27 28 W	Mar. 4	3 p, 5	Mar. 7	29.49	NNW	NNW, 11	N	NNW, 11	Steady.
Gulfking, Am. S. S.	Charleston	Port Arthur	30 30 N	80 30 W	Mar. 7	9 a, 7	do	29.38	S	S, 8	S	—, 10	
Ossining, Am. S. S.	Algiers	Baltimore	36 07 N	71 55 W	Mar. 8	1 a, 8	Mar. 8	29.16	S	S, 10	W	S, 10	S-W.
Edgemoor, Am. S. S.	Houston	Havre	36 20 N	72 15 W	Mar. 9	10 p, 9	Mar. 10	29.39	WNW	WNW, 7	NNW	WNW, 9	WNW-NNW.
Frederik VIII, Dan. S. S.	Oslo	Halifax	56 50 N	18 33 W	Mar. 10	4 a, 10	do	29.65	WNW	WNW, 6	W	—, 9	Steady.
Spidoleine, Belg. M. S.	Amsterdam	Galveston	49 05 N	6 13 W	do	4 p, 10	Mar. 13	29.97	NNW	NNW, 7	WNW	WNW, 10	NNW-W.
Exford, Am. S. S.	Lisbon	New York	37 10 N	64 30 W	Mar. 12	6 p, 12	do	29.66	SSW	W, 7	W	W, 9	S-W-NW.
Scoresby, Br. S. S.	Marmagao	Hamburg	48 30 N	5 30 W	Mar. 9	3 a, 12	Mar. 12	29.46	WNW	WNW, 9	N	WNW, 10	W-NW.
Silverbelle, Br. M. S.	Port Said	New York	36 18 N	49 30 W	Mar. 13	9 p, 13	Mar. 15	29.53	W	W, 10	NW	—, 10	W-WNW.
McKeesport, Am. S. S.	New York	Havre	48 55 N	18 30 W	do	4 a, 13	do	28.98	NNW	N, 7	NE	NW, 10	
Hellig Olav, Dan. S. S.	do	Christiansand	54 20 N	24 22 W	Mar. 14	4 p, 15	do	29.41	N	N, 6	ENE	N, 10	N-ENE.
Wytheville, Am. S. S.	Antwerp	New York	44 26 N	45 45 W	Mar. 18	Noon, 18	Mar. 20	28.82	SSW	NNE, 7	W	NW, 11	
Reventazon, Br. S. S.	Puerto Castilla.	Bremerhaven	39 00 N	65 00 W	do	9 p, 19	Mar. 19	29.46	SSW	NW, —	NW	W, 12	WSW-NW.
Berlin, Ger. S. S.	Bremerhaven	New York	44 13 N	40 19 W	do	—, 19	do	29.07	SW	WSW, 12	NW	—, 12	SW-WNW
Exarch, Am. S. S.	New York	Gibraltar	38 15 N	21 40 W	Mar. 20	4 p, 20	Mar. 21	29.24	WSW	WSW, 9	NW	W, 10	SW-W.
Enton, Br. M. S.	Falmouth	Halifax	47 09 N	37 09 W	Mar. 22	11 p, 22	Mar. 22	29.49	SSW	S, 9	W	S, 10	SE-W.
Florence Luckenbach, Am. S. S.	Canal Zone	New Orleans	27 02 N	88 13 W	Mar. 25	3 a, 25	Mar. 25	29.83	NW	NW, 7	W	WNW, 9	
Waukegan, Am. S. S.	New York	Havre	47 05 N	29 00 W	Mar. 29	4 p, 29	Mar. 31	29.38	WSW	WSW, 8	NNW	NW, 12	SSW-WNW.
Novian, Br. S. S.	Liverpool	Boston	42 55 N	39 47 W	Mar. 30	6 p, 30	do	28.94	SW	WSW, —	NW	W, 12	SSW-SW.
West Madaket, Am. S. S.	Stettin	Mobile	40 05 N	27 45 W	do	2 p, 31	Apr. 1	29.40	SW	WSW, —	W	—, 11	
NORTH PACIFIC OCEAN													
Choyo Maru, Jap. S. S.	Seattle	Yokohama	55 00 N	168 02 W	Feb. 28	6 p, 28	Mar. 1	28.89	SE	S, 10	WSW	S, 10	
Yukon, Am. S. S.	do	Seward	At Sewa	rd, Alaska.	do	7 p, 28	Mar. 2		SE	SE, —		SE, 10	
Tecumseh, Br. S. S.	San Pedro	Nagasaki	32 34 N	165 00 E	Mar. 2	10 a, 2	do	29.45	SE	WSW, 12	NW	WSW, 12	SSW-WSW-N
Nebraskan, Am. S. S.	Los Angeles	New York	13 18 N	94 35 W	do	9 p, 2	Mar. 3	29.98	NE	—, 8	N	—, 8	
Wisconsin, Am. S. S.	Portland	Shanghai	51 26 N	170 55 W	do	7 a, 3	do	29.32	SE	S, —	SW	SW, 11	SE-S-SW
Do	do	do	50 48 N	173 45 W	Mar. 4	2 a, 4	Mar. 5	29.75	W	W, —	W	W, 9	Steady
Kaikyu Maru, Jap. S. S.	Muroran	Port Alberni	49 39 N	179 25 E	Mar. 3	11 p, 3	Mar. 4	28.78	S	SE, 2	SW	WSW, 9	4 pts.
Canadian Inventor, Br. S. S.	Victoria	Panama	39 17 N	124 04 W	Mar. 4	4 a, 4	Mar. 5	29.57	SE	SE, —	SW	SSE, 9	SE-S
Choyo Maru, Jap. S. S.	Seattle	Yokohama	51 53 N	166 22 E	Mar. 7	8 p, 7	Mar. 7	29.57	W	N, 6	W	W, 9	W-N
Olympia, Am. S. S.	Taku Bar	Seattle	45 49 N	164 20 E	Mar. 10	2 a, 10	Mar. 11	29.35	SE	S, 7	NW	SW, 9	SE-S-SW
Oridono Maru, Jap. S. S.	Yokohama	Willapa	50 11 N	163 35 W	do	Mdt, 10	do	29.89	SSW	SSW, 9	SW	SSW, 9	SSW-SW
Hakonesan Maru, Jap. M. S.	Vancouver	Yokohama	52 02 N	149 52 W	Mar. 11	6 a, 12	Mar. 12		SW	WNW, 7	WNW	WNW, 9	W-WNW

OCEAN GALES AND STORMS, MARCH, 1930

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH PACIFIC OCEAN—continued			° ′	° ′				Inches					
Aden Maru, Jap. S. S.	Milke	Iloilo	29 33 N	128 10 E	Mar. 12	2 p, 12	Mar. 13	29.29	E	SW, —	W	SW, 10	SE-SW-W
Tacoma, Am. S. S.	Manila	San Francisco	42 15 N	135 20 W	do	10 p, 13	Mar. 16	29.97	NW	N, 9	NNE	N, 9	N-NNE
Benghalis, Du. S. S.	Borneo	Los Angeles	33 10 N	131 30 W	Mar. 13	2 p, 14	Mar. 15	29.80	NNW	NW, 9	NW	NW, 10	Steady
Makua, Am. S. S.	Hawaii	San Francisco	36 15 N	126 20 W	Mar. 14		Mar. 14	29.46	NW	NW, 9	N	NW, 9	Do.
Wisconsin, Am. S. S.	Portland	Shanghai	50 01 N	177 20 E	Mar. 7	2 p, 8	Mar. 9	29.46	W	WSW, —	NW	WSW, 11	WSW-NW
Do	do	do	49 44 N	176 00 E	Mar. 10	Noon, 10	Mar. 11	29.21	S	S, 8	WNW	SE, 11	S-SE-SW
Do	do	do	44 06 N	151 15 E	Mar. 14	8 p, 14	Mar. 15	29.63	ESE	ESE, 7	SE	ESE, 9	ESE-SE
California, Am. S. S.	Meridian 180°	San Francisco	45 10 N	175 26 W	Mar. 16	8 p, 16	Mar. 16	29.31	N	N, 8	SE	NW, 10	N-NNW.
Hakubasan Maru, Jap. M. S.	Yokohama	do	46 36 N	174 20 W	do	8 p, 17	Mar. 18	29.67	NNE	NE, 10	E	NE, 11	NNE-ENE
Emp. of Asia, Br. S. S.	do	Vancouver	49 32 N	164 17 E	Mar. 17	1 p, 19	Mar. 19	29.79	NE	NNE, 6	NE	NE, 10	Steady
Pres. Madison, Am. S. S.	do	Victoria	48 50 N	144 18 W	Mar. 16	4 a, 21	Mar. 22	29.24	N	W, 6	W	NE, 11	E-W
Ethan Allen, Am. S. S.	San Pedro	Kobe	32 45 N	140 50 E	Mar. 20	7 p, 20	Mar. 21	29.67	NNE	NNE, 6	NNE	NNE, 10	Steady
Nevada, Am. S. S.	Astoria	Yokohama	36° N	140° E	do	4 a, 21	Mar. 22	29.42	S	E, 10	NNW	NNW, 11	ESE-E-N
Tecumseh, Br. S. S.	Yokohama	San Pedro	38 43 N	153 30 E	Mar. 21	7 p, 21	Mar. 21	29.25	SE	SSE, 11	SW	SSE, 11	SE-SSE
Hakonesan Maru, Jap. M. S.	Vancouver	Yokohama	42 00 N	149 20 E	Mar. 20	3 a, 22	Mar. 24	28.92	SE	ESE, 4	NW	NW, 12	ESE-NW
Pres. Pierce, Am. S. S.	Yokohama	San Francisco	29 44 N	178 15 W	Mar. 23	6 p, 24	do	29.56	SW	WNW, 9	WNW	WNW, 9	2 pts.
Steelmaker, Am. S. S.	Honolulu	Yokohama	28 34 N	157 33 E	Mar. 26	6 a, 26	Mar. 28	29.62	SE	SE, 8	NNE	NNE, 9	
Do	do	do	32 15 N	146 01 E	Mar. 29	2 a, 29	Mar. 30	30.15	SSE	S, 8	SSW	SSW, 10	W-NW
Northwestern, Am. S. S.	Seward	Seattle	60 35 N	146 15 W	Mar. 31	8 a, 31	Mar. 31	29.28	SW	—, 6	SE	SW, 9	NE-SW

* Approximate.

NORTH PACIFIC OCEAN

By WILLIS E. HURD

Following upon the abnormal conditions of mean monthly atmospheric pressure which prevailed over some eastern parts of the North Pacific Ocean during the past January and February, the pressure of March settled more nearly into average. The Aleutian cyclone, while it spread on several days over a large area in the central Pacific, at times extending into the Tropics, was central over the upper western waters of the Gulf of Alaska, the minimum station average being 29.71 inches, at Kodiak. The mean pressures over the eastern part of the Bering Sea were raised considerably by the passage of an anticyclone of great magnitude during the 16th to 20th. The HIGH crested at Dutch Harbor and St. Paul on the 17th, giving maxima of 30.78 and 31.06 inches, respectively, which extreme readings appear to be the record high for March at these stations, and near record at Dutch Harbor for all months, being exceeded only in January, 1916, and February, 1922.

The California-Pacific anticyclone attained a high state of development which persisted through the greater part of the month. A feature was its local intrusion upon the coast of Washington and vicinity, where monthly pressures above normal occurred, whereas farther north and south coastal averages were below the normal.

Much high pressure prevailed on the Asiatic coast and over adjacent waters, resulting in some activity of the northeast monsoon. Its regularity, however, was considerably broken by several disturbances in low latitudes, one of which became a typhoon, and by several rather deep depressions which entered or formed over upper waters.

Barometric data for several island and coast stations in west longitudes, including Point Barrow on the Arctic Ocean, are given in the following table:

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level at indicated hours, North Pacific Ocean and adjacent waters, March, 1930*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	Inch	Inches		Inches	
Point Barrow [1]	30.06		30.74	17th	29.22	1st.
Dutch Harbor [1]	29.85	+0.11	30.78	17th	29.20	26th.
St. Paul [1]	29.86	+0.11	31.06	17th	29.16	4th.
Kodiak [1]	29.71	−0.04	30.52	18th	28.86	5th.[2]
Midway Island [1]	30.07	−0.01	30.42	30th	29.56	23d.
Honolulu [3]	30.02	−0.02	30.16	4th	29.84	23d.
Juneau [3]	29.80	−0.14	30.70	29th	29.25	7th.
Tatoosh Island [3 4]	30.07	+0.09	30.43	26th	29.58	21st.
San Francisco [3 4]	29.98	−0.07	30.34	22d	29.37	14th.
San Diego [3 4]	29.97	−0.05	30.29	21st	29.61	14th.

[1] P. m. observations only.
[2] And on other date.
[3] A. m. and p. m. observations.
[4] Corrected to 24-hour mean.

The month may properly be called a stormy one on the North Pacific, since the vessel record, incomplete though it doubtless is at the present writing, shows eight days on which full storm to hurricane velocities occurred, in addition to several other days with whole gales. On the whole, however, storm conditions were less pronounced and widespread than in February, and much less so than in January, while they were only slightly more severe than in November and December of last year. For the entire period of five months it may safely be said there was an unusual succession of stormy weather. The higher

wind forces of March were encountered on the 2d, 3d, 8th, 10th, 17th, 18th, 21st, and 22d, with strong probabilities of their occurrence on one or more other dates.

On the 2d hurricane velocities were recorded in 32°–33° north latitude, 165° east longitude, in connection with what was apparently a fairly deep but short-lived cyclone. On the 3d, 17th, and 18th winds of force 11 occurred immediately south of the central Aleutians, and of lesser force over a considerably larger area. On the 8th and 10th the heavy gales were apparently confined to the western Aleutians.

The storm to hurricane velocities which were reported for the 21st and 22d are credited to the only typhoon of the month. This tropical cyclone originated, according to current information, southeast of Taiwan on the 19th. It moved northeastward, skirting the southern Japanese coast on the Pacific side, where it caused whole gales on the 20th, and when east of Hondo became intense, developing hurricane velocities on the two following days which persisted until the storm was east of Yezo, when it began losing vigor. On the 24th, when south of Kamchatka, it turned eastward, then again northeastward toward the Aleutian Islands, where it seems to have become identified with the semipermanent LOW of that region. Crossing the islands on the 27th, it moved northward as a shallow depression, and lost identity on the 28th south of Nome.

In addition to the severer gales mentioned as occurring south of the Aleutians, lesser gales, fresh to whole, were experienced along the northern routes across this region from the 1st to the 16th. In the Eastern and Japan Seas moderately severe gales occurred on the 12th and 13th, associated with a rather deep depression which originated in the upper part of the China Sea on the 11th and moved northward gaining intensity for two days, then practically dispersing in the Japan Sea on the 14th.

In the neighborhood of Midway Island fresh to strong gales were experienced by vessels on the 20th to 27th in connection with a disturbance which developed in the lower region of a trough of low pressure which extended from Alaska to the tropics. After reaching its fullest development north of Midway on the 23d, on which date pressure at the island dropped to 29.56 inches, the disturbance slowly withdrew to upper waters.

Between California and a region about midway thence to the Hawaiian Islands, two somewhat energetic cyclones occurred during the initial half of the month. The earlier, which began in February, caused fresh to whole gales from the 1st to the 4th of March midway along the routes, and on the 4th along the upper California coast. The second, which formed near San Francisco on the 13th, as the result of a westward extension of a cyclone central over Nevada, developed on the 14th and 15th off the coast, and caused moderate to whole gales at sea between the one hundred and twenty-fifth and one hundred and thirty-fifth meridians.

Fresh to strong gales occurred on several days in the upper part of the Gulf of Alaska, and on one day, the 24th, off Lower California.

Northers of force 8 blew in the Gulf of Tehuantepec on the 2d and 9th.

The prevailing wind direction at Honolulu was from the east, with a maximum velocity at the rate of 32 miles an hour from the same direction on the 2d. It was a more than ordinarily windy March at this station.

Fog, while comparatively infrequent, was more widely and uniformly distributed over the middle and upper ocean than it had been for several months, now appearing on about 5 to 10 per cent of the days in upper east longitudes, where it had been practically absent since the preceding autumn. Fog occurred on one to five days in west longitudes nearly along the fiftieth parallel, and on three to six days along the coast of the United States, where there was a marked decrease in its formation from that of February. On the night of the 25th–26th dense fog set in at the mouth of the Columbia River, where the French steamship *Arkansas* reported six ships in close proximity to each other lying at anchor waiting for it to clear.

CLIMATOLOGICAL TABLES[1]

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, March, 1930

Section	Temperature							Precipitation					
			Monthly extremes							Greatest monthly		Least monthly	
	Section average	Departure from the normal	Station	Highest	Date	Station	Lowest	Date	Section average	Departure from the normal	Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	52.4	−3.7	Brewton (near)	81	17	2 stations	19	[2] 2	5.64	−0.09	Lock No. 4	8.51	Seven Hills	2.22
Arizona	51.8	−1.0	Parker	102	26	Fort Valley	−11	1	2.06	+0.92	Crown King	5.71	Agua Caliente	0.00
Arkansas	50.4	−2.3	Harrison	83	20	2 stations	15	2	2.21	−2.53	Wynne	7.55	Gravette	0.54
California	51.9	+1.3	Greenland Ranch	100	25	Sierraville	−8	1	3.29	−0.56	Squirrel Inn	9.14	Greenland Ranch	0.07
Colorado	32.5	−1.8	Holly	82	16	Dillon	−31	27	0.89	−0.44	Savage Basin	6.30	3 stations	0.00
Florida	62.0	−3.7	Venus	91	23	6 stations	28	[2] 3	7.37	+4.31	Inverness	12.88	Coral Gables	2.12
Georgia	52.4	−4.3	Waycross	82	1	Clayton	14	3	5.77	+0.98	Thomasville	10.66	Hartwell	3.25
Idaho	38.1	+2.0	Lapwai	79	11	Big Springs	−28	3	1.31	−0.25	Pete King Ranger Station.	6.32	Dubois	T.
Illinois	40.3	−0.3	Pontiac	80	16	Aledo	7	2	1.54	−1.67	Chicago	3.46	Astoria	0.43
Indiana	39.4	−1.3	2 stations	76	[2] 16	Plymouth	4	3	1.82	−2.04	La Porte	4.23	Princeton	0.71
Iowa	37.3	+2.7	do	80	16	Sanborn	−4	2	0.89	−0.88	Mount Ayr	2.42	Inwood	0.04
Kansas	42.3	−1.5	4 stations	81	[2] 12	St. Francis	0	3	0.29	−1.15	Emporia	0.97	Ness City	0.00
Kentucky	44.5	−1.8	Lovelaceville	76	15	Mount Sterling	9	3	2.17	−2.53	Vanceburg	4.25	Woodbury	0.97
Louisiana	56.7	−4.0	2 stations	84	[2] 17	3 stations	23	4	3.63	−1.04	Paradis	7.64	Shreveport	1.24
Maryland-Delaware	42.4	−0.2	do	77	17	Oakland, Md	4	5	2.14	−1.52	State Sanatorium, Md.	4.45	Solomons, Md	0.65
Michigan	29.8	0.0	Monroe	74	16	Dukes	−15	14	1.68	−0.56	Sack Bay	3.82	Sidnaw	0.34
Minnesota	27.8	+1.7	5 stations	75	16	Park Rapids	−21	2	0.50	−0.64	Pigeon River Bridge	2.33	2 stations	T.
Mississippi	54.1	−2.8	2 stations	80	[2] 9	Holly Springs	22	3	4.10	−1.70	Columbus	6.90	Austin	2.06
Missouri	43.2	−0.7	Lamonte	88	16	Grant City	6	2	1.37	−1.65	Caruthersville	4.50	Nevada	0.04
Montana	30.5	+0.4	Upper Yaak River	75	28	Hebgen Dam	−30	3	0.90	+0.03	Adel	3.41	Baker	0.00
Nebraska	36.9	+1.0	McCook	87	16	3 stations	−6	2	0.42	−0.68	Tecumseh	1.32	2 stations	0.00
Nevada	42.4	+1.2	Las Vegas	88	25	Lamoille	−5	1	0.64	−0.31	Marlette Lake	3.23	Imlay	T.
New England	32.4	+0.1	Springfield, Mass	68	7	Ripogenus Dam, Me.	−23	4	4.12	+0.87	West Rockport, Me.	8.78	Bethlehem, N. H	1.35
New Jersey	40.0	+1.6	Indian Mills	78	18	2 stations	9	[2] 5	2.54	−1.32	Belvidere	3.80	Asbury Park	0.44
New Mexico	40.7	−2.8	Carlsbad	83	30	Elizabethtown	−19	28	0.82	−0.02	Skeleton Canyon	3.95	Newman	0.00
New York	32.3	+0.2	2 stations	70	17	2 stations	−10	4	3.53	+0.52	Conklingville	6.14	Gabriels	1.52
North Carolina	47.2	−2.3	Newbern	79	18	Mount Mitchell	−14	3	2.81	−1.50	Andrews	7.72	Hendersonville	0.96
North Dakota	26.1	+3.5	Oakes	62	19	Park River	−17	20	0.09	−0.74	Power	0.80	6 stations	0.00
Ohio	38.3	−1.0	McConnelsville	78	17	2 stations	6	3	2.77	−0.66	McConnelsville	4.19	St. Paris	1.34
Oklahoma	49.3	−1.8	Cherokee	82	16	do	5	[2] 2	0.62	−1.64	Tuskahoma	2.92	2 stations	0.00
Oregon	44.5	+2.5	McMinnville	87	28	do	−3	[2] 1	1.67	−1.39	Government Camp	6.79	Bear Creek	0.04
Pennsylvania	37.9	+0.4	Phoenixville	78	17	Brookville	−9	3	3.03	−0.51	Arendtsville	5.05	Mount Pocono	1.04
South Carolina	50.9	−3.9	Conway	80	18	Walhalla	15	3	3.40	−0.57	Ferguson	6.32	Darlington	0.63
South Dakota	32.4	+1.3	3 stations	75	15	Timber Lake	−11	2	0.51	−0.51	2 stations	3.20	Leola	0.00
Tennessee	47.3	−2.1	Etowah	77	16	2 stations	11	3	4.73	−0.61	Pheasant Field	7.65	Dover	2.02
Texas	55.1	−3.6	Riogrande	104	6	Spearman	6	3	1.73	−0.33	Bronson	5.28	Muleshoe	0.00
Utah	39.5	+1.2	St. George	81	25	Ibapah	−10	1	1.09	−0.33	Silver Lake	3.63	Lucin	T.
Virginia	44.6	−1.3	3 stations	78	[2] 17	Burkes Garden	2	3	2.09	−1.64	Rocky Mount	4.42	Mineral	0.68
Washington	43.0	+2.2	Castle Rock	85	28	Sullivan Lake	−3	2	2.65	−0.71	Big Four	12.88	Wahluke	0.05
West Virginia	40.3	−2.3	Romney	79	25	Pickens	0	3	3.21	−0.73	Pickens	6.03	Upper Tract	0.20
Wisconsin	30.3	+1.2	2 stations	75	16	Danbury	−14	2	1.26	−0.45	Fond du Lac	3.01	Grantsburg	0.20
Wyoming	29.1	−0.7	do	68	[2] 13	Snake River	−30	3	0.89	−0.10	Snake River	2.73	2 stations	0.15
Alaska (Feb.)	−2.4	−11.4	do	50	[2] 5	Eagle	−65	11	1.94	−0.10	Calder	17.96	Talkeetna	T.
Hawaii	69.3	+0.5	do	89	[2] 20	Puu Kapele	41	12	9.76	+1.36	Puohakamoa No. 2	38.00	Kailua	1.07
Porto Rico	74.2	+0.3	Coloso	95	25	Guineo Reservoir	50	3	2.24	−1.24	Mona Island	5.10	Central Aguirre	0.67

[1] For description of tables and charts, see REVIEW, January, 1930, p. 37.
[2] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, March, 1930*

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. +, mean min. + 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	°F.	In.	In.		Miles							0–10	In.	In.
New England							34.6	+1.9											69	3.74	+0.3										5.1		
Eastport	76	67	85	29.59	29.68	−0.25	30.5	+1.6	47	10	38	5	4	24	30	27	20	66		2.92	−0.9	14	9,200	w.	51	ne.	8	11	6	14	5.9	5.9	0.0
Greenville, Me	1,070	6	----	28.49	29.69	------	24.6	------	46	12	33	−11	4	16	36	----	----	----		6.22	------	15	6,584	nw.	33	----	22	9	12	10	----	28.5	19.0
Portland, Me	103	82	117	29.61	29.74	−.22	33.4	+1.6	55	13	41	12	4	26	24	29	22	67		8.02	+4.2	13	7,033	nw.	34	nw.	22	15	7	9	4.5	1.3	0.0
Concord	289	70	79	29.42	29.74	−.26	33.3	+2.5	56	26	42	7	5	24	33	----	----	----		4.34	+1.3	10	5,487	nw.	26	ne.	8	15	10	6	4.0	1.7	0.0
Burlington	403	11	48	29.31	29.77	−.23	28.8	−0.3	49	7	36	1	4	21	34	----	----	----		3.62	+1.6	10	6,796	nw.	46	s.	1	6	11	14	6.5	19.5	T.
Northfield	876	12	60	----	29.76	−.24	27.8	+1.4	50	26	37	−4	5	19	39	----	----	----		3.61	+1.0	11	4,756	n.	22	se.	11	5	12	14	6.8	7.5	T.
Boston	125	106	165	29.61	29.75	−.22	38.3	+2.7	60	10	46	19	3	31	24	33	25	62		3.02	−0.6	11	6,679	nw.	26	nw.	14	12	12	7	4.8	0.6	0.0
Nantucket	12	14	90	29.74	29.75	−.23	37.8	+2.3	58	25	44	21	22	32	21	34	30	74		3.05	−0.7	9	11,596	w.	43	sw.	27	12	13	6	4.9	1.9	0.0
Block Island	26	11	48	29.74	29.77	−.21	37.8	+2.4	52	11	44	19	3	32	21	34	30	75		2.35	−1.5	9	14,043	w.	58	w.	2	14	7	10	4.3	0.4	0.0
Providence	160	215	251	29.58	29.76	−.22	37.8	+2.1	58	10	46	18	3	30	24	33	24	61		3.02	−0.5	9	9,672	nw.	48	nw.	3	15	10	6	4.1	T.	0.0
Hartford	159	122	----	29.59	29.76	−.23	37.2	+2.2	60	13	45	16	3	29	26	----	----	----		3.64	−0.3	9	------	nw.	----	----	----	11	7	13	5.2	T.	0.0
New Haven	106	74	153	29.67	29.79	−.20	38.4	+2.6	62	13	46	18	3	30	28	34	28	70		3.50	−0.6	9	6,898	nw.	30	sw.	27	11	12	8	4.7	T.	0.0
Middle Atlantic States							42.1	+1.3											64	2.17	−1.3									5.0		
Albany	97	107	115	29.68	29.79	−.22	35.9	+3.2	59	13	44	13	3	28	30	30	24	68		2.76	+0.1	12	5,266	s.	27	se.	11	11	13	7	4.6	1.1	0.0
Binghamton	871	10	84	28.85	29.80	−.22	34.6	+2.0	68	17	44	13	3	26	35	----	----	----		2.46	−0.2	14	5,326	nw.	23	nw.	9	5	10	16	6.7	2.4	0.0
New York	314	414	454	29.45	29.80	−.20	39.8	+2.1	62	13	48	17	3	32	29	34	25	59		2.16	−1.5	8	13,641	nw.	55	nw.	3	9	12	10	5.7	T.	0.0
Bellefonte	1,050	5	36	28.68	29.81	------	35.7	------	68	17	47	14	3	25	39	30	25	71		2.31	------	11	------	w.	----	----	----	11	4	16	5.9	2.6	0.0
Harrisburg	374	94	104	29.43	29.84	−.19	40.8	+1.9	71	17	50	19	22	32	32	34	26	59		3.84	+0.8	10	5,977	w.	33	sw.	27	13	9	9	4.9	1.2	0.0
Philadelphia	114	123	367	29.71	29.84	−.18	43.7	+2.9	74	17	52	21	3	35	32	37	30	64		2.58	−0.8	8	10,710	nw.	39	sw.	25	9	14	8	5.2	T.	0.0
Reading	325	81	96	29.47	29.82	------	41.1	+1.1	72	17	50	19	3	32	34	34	27	61		2.07	−1.4	8	5,943	w.	32	e.	7	12	11	8	4.7	T.	0.0
Scranton	805	111	119	28.92	29.80	−.22	36.6	+0.9	70	17	46	14	3	27	33	32	26	66		2.26	−0.9	10	6,050	sw.	26	sw.	1	6	11	14	6.5	1.7	0.0
Atlantic City	52	37	172	29.77	29.83	−.19	41.8	+3.2	65	17	49	20	3	34	26	36	30	67		1.30	−2.3	7	12,694	w.	62	e.	8	12	13	6	4.6	T.	0.0
Cape May	17	13	49	----	----	------	42.6	+1.8	69	17	51	22	22	34	28	37	32	70		1.42	−2.3	8	------	nw.	----	----	----	16	10	5	----	T.	0.0
Sandy Hook	22	10	55	29.76	29.78	------	39.4	------	58	13	46	19	3	33	23	35	29	69		1.68	−2.4	10	11,938	nw.	44	ne.	8	11	11	9	5.1	T.	0.0
Trenton	190	159	183	29.60	29.81	------	41.0	+1.9	73	17	51	18	3	31	36	35	27	62		2.66	−0.7	10	8,965	nw.	38	nw.	2	11	13	7	4.7	T.	0.0
Baltimore	123	100	215	29.71	29.84	−.19	45.2	+2.9	76	17	54	23	3	36	37	38	29	59		2.27	−1.4	6	8,559	sw.	40	sw.	27	15	6	10	4.5	T.	0.0
Washington	112	62	85	29.73	29.85	−.19	45.0	+2.4	75	17	55	21	3	35	40	37	27	56		2.26	−1.5	6	5,786	nw.	32	nw.	12	15	9	7	4.3	T.	0.0
Cape Henry	18	8	54	29.85	29.86	------	47.0	+0.4	77	18	56	23	4	38	35	42	37	73		2.26	−1.6	10	8,460	sw.	34	nw.	2	12	10	9	4.7	0.0	0.0
Lynchburg	681	153	188	29.14	29.89	−.16	45.4	−1.9	73	13	56	18	3	35	41	37	28	54		2.26	−1.3	4	6,151	w.	37	w.	25	13	13	5	4.4	T.	0.0
Norfolk	91	170	205	29.79	29.89	−.14	48.2	0.0	74	18	57	24	4	39	29	41	34	65		1.68	−2.1	10	9,852	w.	42	w.	2	15	6	10	4.7	0.0	0.0
Richmond	144	11	52	29.72	29.88	−.16	46.4	−0.8	76	17	58	22	3	35	36	38	29	56		1.07	−2.6	9	6,792	w.	45	s.	7	13	8	10	4.6	0.0	0.0
Wytheville	2,304	49	55	27.47	29.88	−.17	40.4	−1.9	65	16	51	9	3	30	36	34	27	64		2.03	−1.4	11	6,069	w.	32	w.	26	12	11	8	4.8	3.6	0.0
South Atlantic States							51.4	−2.3											68	3.71	0.0									5.1		
Asheville	2,253	70	84	27.53	29.93	−.13	43.0	−1.9	68	13	54	12	3	32	38	36	29	66		1.66	−2.3	11	6,538	nw.	28	n.	19	13	10	8	4.7	0.5	0.0
Charlotte	779	55	62	29.06	29.91	−.14	48.8	−1.6	72	13	59	20	3	38	32	42	34	63		2.45	−1.7	12	4,760	sw.	24	sw.	25	15	7	9	4.5	0.0	0.0
Greensboro	886	5	56	28.94	29.91	------	45.3	------	73	13	58	16	3	33	43	38	31	67		2.21	------	10	6,861	sw.	33	sw.	25	12	9	10	4.5	0.5	0.0
Hatteras	11	5	50	29.88	29.90	−.14	51.5	−0.5	68	24	58	31	3	45	25	47	43	74		3.15	−1.1	11	10,890	sw.	42	nw.	2	13	7	11	5.1	T.	0.0
Raleigh	376	103	110	29.49	29.90	−.15	48.8	−1.4	74	13	59	22	3	38	35	43	38	70		2.33	−1.5	11	5,568	sw.	30	se.	7	16	4	11	4.6	0.2	0.0
Wilmington	78	81	91	29.85	29.94	−.11	52.1	−1.2	72	17	61	27	4	43	29	47	42	75		2.98	−0.2	12	5,727	w.	26	w.	2	11	9	11	5.4	0.0	0.0
Charleston	48	11	92	29.90	29.95	−.11	54.8	−2.6	72	1	62	29	3	47	28	48	42	69		4.17	+1.2	13	7,501	w.	30	nw.	2	10	8	13	5.6	0.0	0.0
Columbia, S. C	351	41	57	29.56	29.95	−.11	51.5	−3.7	73	13	61	24	3	42	33	44	36	63		2.31	−1.1	13	6,212	sw.	30	sw.	25	14	8	9	4.8	0.0	0.0
Due West	711	10	55	29.18	29.96	------	48.6	------	71	21	58	21	3	39	33	----	----	----		2.96	------	12	7,975	sw.	38	w.	25	12	9	10	4.9	0.0	0.0
Greenville, S. C	1,039	139	146	28.81	29.91	------	48.6	−1.3	70	13	58	20	3	39	29	42	36	68		3.51	−1.6	9	7,344	w.	38	w.	2	12	9	10	4.9	0.0	0.0
Augusta	182	62	77	29.74	29.94	−.12	52.8	−3.4	74	13	62	26	3	43	36	45	38	65		4.08	0.0	14	4,758	nw.	26	w.	25	9	11	11	5.2	0.0	0.0
Savannah	65	150	194	29.89	29.96	−.10	55.3	−3.7	76	18	63	29	3	47	29	48	42	70		4.22	+1.2	15	9,054	w.	38	nw.	2	10	5	16	6.4	0.0	0.0
Jacksonville	43	209	245	29.93	29.98	−.08	58.7	−3.9	80	1	66	34	3	52	22	51	45	70		10.00	+7.1	14	8,595	w.	38	nw.	2	7	9	15	6.2	0.9	0.0
Florida Peninsula							68.2	−1.7											77	5.78	+3.8									5.7		
Key West	22	10	64	29.96	29.98	−.07	72.1	−0.5	85	22	77	52	4	67	17	66	63	79		3.71	+2.3	8	7,157	n.	36	nw.	25	12	11	8	4.8	0.0	0.0
Miami	25	124	168	29.97	30.00	−.09	69.0	−1.2	88	20	76	41	4	62	24	62	59	74		3.76	+1.6	9	7,701	s.	29	sw.	29	7	11	13	6.2	0.0	0.0
Tampa	35	79	197	29.96	29.99	−.08	63.4	−3.4	80	19	71	39	4	56	28	57	54	77		9.87	+7.4	14	8,024	n.	34	se.	7	6	4	21	7.0	0.0	0.0
Titusville	44	5	----	29.94	29.99	------	63.4	------	88	1	72	35	4	54	34	----	----	----		9.54	------	13	------	nw.	----	----	----	13	7	11	4.9	0.0	0.0
East Gulf States							54.0	−3.6											69	6.01	+0.8									6.0		
Atlanta	1,173	190	216	28.70	29.96	−.10	49.3	−2.7	70	21	58	21	3	41	26	42	34	62		4.34	−1.0	9	8,826	nw.	38	nw.	2	10	6	15	5.7	T.	0.0
Macon	370	78	87	29.57	29.98	−.08	52.5	−4.2	74	18	62	28	3	43	36	45	38	64		4.80	−0.2	14	5,169	w.	25	s.	6	11	4	16	5.5	T.	0.0
Thomasville	273	49	103	29.69	29.99	−.07	55.7	−4.5	78	18	64	31	3	47	28	49	44	71		10.66	+6.6	15	5,248	nw.	21	w.	25	7	7	17	6.6	0.0	0.0
Apalachicola	36	11	51	29.96	30.00	------	57.3	------	76	1	64	36	3	51	25	52	48	75		8.23	+4.0	12	6,612	nw.	32	e.	28	7	9	15	6.3	0.0	0.0
Pensacola	56	149	185	29.95	30.01	−.05	55.9	−4.4	70	1	62	34	3	50	20	51	46	74		4.38	−0.4	14	9,406	n.	40	n.	1	7	6	18	6.6	0.0	0.0
Anniston	741	9	57	29.19	30.00	−.06	50.6	−1.9	74	21	61	23	3	40	35	----	----	----		8.30	+2.7	9	4,570	nw.	20	w.	25	12	10	9	5.1	T.	0.0
Birmingham	700	11	48	29.21	29.99	−.07	52.2	−3.2	74	21	62	23	3	42	29	44	37	63		6.80	+1.1	9	5,471	w.	28	s.	6	12	4	15	5.7	T.	0.0
Mobile	57	125	161	29.94	30.00	−.06	56.4	−3.3	76	18	64	34	3	49	26	51	46	76		3.22	−2.8	15	7,105	nw.	33	sw.	7	6	10	15	6.6	0.0	0.0
Montgomery	223	100	112	29.75	30.00	−.06	54.2	−3.6	74	18	62	29	3	46	28	47	40	64		4.93	−1.1	13	5,343	nw.	24	w.	1	11	6	14	5.8	0.0	0.0
Corinth	469	6	----	----	----	------	51.0	------	76	15	63	24	3	40	37	----	----	----		5.02	------	9	------	se.	----	----	----	7	16	8	----	0.0	0.0
Meridian	375	87	95	29.59	30.00	−.05	53.3	−3.8	71	17	63	28	3	44	34	46	40	68		6.41	+1.2	11	4,528	sw.	25	nw.	1	10	7	14	5.7	0.0	0.0
Vicksburg	247	65	73	29.74	30.02	−.02	54.4	−4.1	71	14	63	31	3	46	30	47	40	65		4.15	−1.4	11	5,262	nw.	27	nw.	1	9	7	15	6.1	T.	0.0
New Orleans	53	76	84	29.96	30.02	−.02	59.2	−3.6	81	18	66	40	4	52	24	54	51	79		5.88	+1.2	16	5,041	ne.	23	nw.	25	8	10	13	6.5	0.0	0.0
West Gulf States							56.0	−3.3											67	1.88	−0.9									5.6		
Shreveport	249	77	93	29.74	30.01	−.01	55.0	−3.3	77	20	64	28	3	46	32	48	42	67		1.24	−2.9	8	4,725	nw.	25	sw.	6	14	7	10	5.0	0.0	0.0
Bentonville	1,303	11	44	28.57	29.95	−.06	46.3	−1.0	72	15	57	16	2	36	33	----	----	----		0.82	------	7	5,314	nw.	26	nw.	11	22	6	3	----	T.	0.0
Fort Smith	457	79	94	29.48	29.97	−.04	50.8	−1.8	76	20	61	25	3	40	38	43	35	61		0.75	−2.3	6	6,286	e.	28	nw.	6	14	8	9	4.8	T.	0.0
Little Rock	357	136	153	29.59	29.98	−.05	52.1	−0.9	75	20	62	26	3	42	36	44	34	56		1.99	−2.6	7	6,734	nw.	32	nw.	11	12	7	12	4.8	T.	0.0
Austin	605	136	148	29.36	30.00	------	56.9	−3.8	87	6	67	31	3	46	34	50	44	68		2.09	−0.2	8	6,217	s.	31	n.	24	10	9	12	5.6	T.	0.0
Brownsville	57	83	100	29.91	29.97	------	64.5	−3.7	86	24	73	38	30	56	32	58	55	79		1.41	+0.2	9	7,794	se.	37	n.	1	7	6	18	6.8	0.0	0.0
Corpus Christi	20	11	78	29.98	30.00	+.02	61.2	−3.8	91	6	68	41	30	54	28	56	52	75		2.21	+0.6	10	7,995	e.	32	n.	27	6	4	21	7.3	0.0	0.0
Dallas	512	220	227	29.45	30.00	------	54.4	------	80	6	65	26	3	44	32	----	----	----		2.36	−0.5	8	9,153	se.	47	sw.	6	18	8	5	3.1	T.	0.0
Fort Worth	670	106	114	29.28	29.99	+.01	55.4	−2.3	80	6	67	30	3	44	34	46	35	53		2.86	+0.5	10	6,512	nw.	32	sw.	6	12	8	11	5.2	0.0	0.0
Galveston	54	106	114	29.98	30.04	+.03	58.4	−4.0	73	24	64	38	3	53	19	53	49	76		1.05	−1.6	8	7,661	se.	32	n.	1	7	8	16	6.4	0.0	0.0
Groesbeck	461	11	56	29.52	30.01	------	54.4	------	83	6	64	29	3	44	32	----	----	----		2.38	−0.3	12	7,990	s.	42	sw.	18	12	9	10	5.1	0.0	0.0
Houston	138	292	314	29.88	30.03	------	57.8	−5.5	76	6	65	34	3	50	27	----	----	----		1.58	−1.9	5	8,696	se.	31	ne.	27	9	7	15	6.3	T.	0.0
Palestine	510	64	72	29.48	30.02	+.02	54.6	−4.5	81	6	64	28	3	45	31	48	42	69		2.15	−1.3	9	5,584	s.	28	s.	18	14	8	9	4.8	T.	0.0
Port Arthur	34	58	66	29.99	30.03	------	57.8	------	72	17	65	34	3	51	26	----	----	----		1.78	−1.5	11	5,711	n.	31	n.	1	8	5	18	6.8	0.0	0.0
San Antonio	693	119	132	29.27	30.00	+.02	58.8	−4.0	91	6	69	33	3	49	32	50	43	62		1.76	−0.1	7	4,840	ne	26	ne.	24	9	6	16	6.0	0.0	0.0
Taylor	571	55	63	29.43	30.04	+.05	55.6	−4.1	86	6	68	29	3	45	31	----	----	----		2.61	+0.5	9	6,292	s.	26	n.	24	8	13	10	5.4	0.9	0.0

TABLE 1.—*Climatological data for weather bureau stations, March, 1930*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
Ohio Valley and Tennessee	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	° *F.*	° *F.*	°*F.*		°*F.*	° *F.*	°*F.*	°*F.*	° *F.*	° *F.*	° *F.*	%	° *F.*	*In.*	*In.*		*Miles*							*0–10*	*In.*	*In.*
							42.6	−1.6											66	2.82	−1.3										6.0		
Chattanooga	762	190	215	29.13	29.95	−0.11	48.7	−2.5	73	21	58	20	3	39	31	41	32	57	6.00	+0.2	10	6,441	sw.	38	sw.	25	9	14	8	5.1	0.1	0.0
Knoxville	995	102	111	28.86	29.93	−.13	47.0	−1.7	70	21	58	19	3	37	33	40	33	64	4.41	−0.6	13	5,343	sw.	30	sw.	25	13	8	10	4.8	T.	0.0
Memphis	399	76	97	29.53	29.96	−.08	51.2	−1.1	72	15	59	26	3	43	24	44	37	63	3.12	−2.1	7	6,451	sw.	34	nw.	11	13	7	11	4.9	T.	0.0
Nashville	546	168	191	29.38	29.97	−.08	47.4	−1.8	71	17	57	21	3	37	31	40	33	63	5.14	0.0	8	7,267	w.	37	nw.	11	16	7	8	4.5	0.1	0.0
Lexington	989	193	230	28.85	29.94	−.11	40.8	−2.9	67	13	50	13	3	31	35				2.54	−1.8	12	11,213	sw.	40	w.	26	12	10	9	4.8	1.6	0.0
Louisville	525	188	234	29.34	29.93	−.12	43.4	−2.0	71	13	53	19	3	34	33	37	30	65	1.62	−2.8	7	9,133	sw.	38	sw.	26	11	12	8	4.8	0.4	0.0
Evansville	431	76	116	29.46	29.93	−.11	44.5	−1.4	72	13	54	21	2	35	32	38	32	65	1.97	−2.2	8	7,802	w.	35	w.	11	7	17	7	5.3	4.0	0.0
Indianapolis	822	194	230	28.98	29.89	−.15	39.1	−0.9	70	16	48	16	2	30	33	33	27	66	1.80	−2.1	8	9,640	w.	40	w.	26	13	7	11	5.2	3.0	0.0
Royal Center	736	11	55	29.06	29.87	.....	35.7	.....	72	16	45	11	2	27	32	.....	.....	.....	1.60	−1.3	11	9,473	w.	34	w.	11	13	4	14	5.4	5.4	T.
Terre Haute	575	96	129	29.27	29.90	.....	40.6	.....	70	16	50	17	2	31	32	35	29	68	1.07	−2.7	9	7,978	w.	36	w.	26	9	10	12	5.5	4.5	0.0
Cincinnati	627	11	51	29.20	29.89	−.16	41.0	+0.1	72	17	51	15	3	31	35	35	28	66	1.91	−2.0	9	7,136	sw.	28	sw.	26	13	9	9	4.8	2.3	0.0
Columbus	822	179	222	28.98	29.87	−.17	38.6	−0.5	70	16	48	10	3	30	30	34	29	72	2.13	−1.4	13	8,451	w.	40	w.	12	12	4	15	5.8	4.1	0.0
Dayton	899	137	173	28.91	29.88	.....	39.6	−0.9	70	16	48	14	3	31	31	34	29	71	1.97	−1.7	10	8,065	w.	30	w.	26	13	8	10	5.2	3.5	0.0
Elkins	1,947	59	67	27.79	29.90	−.15	36.6	−3.4	65	16	48	7	5	25	41	31	26	73	3.47	−0.3	15	5,182	w.	27	w.	2	10	7	14	5.9	11.2	0.0
Parkersburg	637	77	82	29.23	29.90	−.15	40.8	−2.0	71	16	51	13	3	31	38	34	28	67	3.55	+0.1	11	5,242	sw.	30	nw.	11	10	8	13	5.9	5.1	0.0
Pittsburgh	842	353	410	28.94	29.85	−.19	37.8	−1.8	68	16	47	12	3	29	34	33	27	70	2.82	−0.2	13	8,702	w.	48	w.	12	8	8	15	6.1	7.3	0.0
Lower Lake Region							33.0	0.0										75	3.31	+0.6									6.8		
Buffalo	767	247	280	28.95	29.79	−.23	30.0	−1.1	50	10	36	13	2	24	20	28	24	78	3.34	+0.8	17	13,041	w.	44	w.	27	5	8	18	7.0	10.3	T.
Canton	448	10	61	29.27	29.76	.....	26.8	−0.9	50	11	35	−7	4	19	42	.....	.....	.....	4.38	+1.9	15	7,626	w.	35	e.	26	8	7	16	6.7	16.1	T.
Ithaca	836	5	100	28.87	29.79	.....	32.2	+0.4	66	17	41	12	4	24	35	28	24	77	3.92	+1.6	13	7,422	nw.	33	se.	25	5	4	22	7.5	12.8	0.0
Oswego	335	76	91	29.41	29.79	−.22	31.9	+0.7	58	17	38	10	4	26	25	29	24	75	3.53	+1.0	16	7,965	w.	29	nw.	19	6	8	17	7.2	9.2	0.0
Rochester	523	86	102	29.23	29.81	−.21	31.8	0.0	62	17	38	15	3	25	29	28	23	72	4.59	+1.8	21	7,044	w.	26	w.	19	8	5	18	6.4	17.8	T.
Syracuse	596	65	79	29.14	29.79	−.22	33.6	+2.2	59	17	40	13	4	27	25	.....	.....	.....	4.18	+1.2	17	6,098	w.	24	w.	21	6	6	19	7.2	8.3	0.0
Erie	714	130	166	29.04	29.83	−.19	33.1	−0.4	65	17	40	14	3	26	32	30	26	75	3.06	+0.4	16	10,124	sw.	36	sw.	5	6	13	12	6.1	11.6	0.0
Cleveland	762	267	337	29.00	29.83	−.20	35.7	+1.1	69	17	43	13	3	28	35	31	26	70	2.68	0.0	14	11,198	w.	42	nw.	8	8	6	17	6.5	4.3	0.0
Sandusky	629	5	67	29.14	29.84	−.19	36.0	+0.9	71	16	44	14	3	28	37	.....	.....	.....	3.71	+1.0	14	7,551	sw.	30	w.	12	10	10	11	5.7	7.5	0.0
Toledo	628	208	243	29.16	29.86	−.17	35.2	−0.1	71	16	43	13	3	28	38	30	25	71	2.76	+0.2	12	10,481	w.	37	nw.	12	13	5	13	5.0	4.4	0.0
Fort Wayne	856	113	124	28.92	29.86	.....	35.6	−3.3	71	16	44	11	3	27	32	31	26	73	1.60	−1.6	9	7,456	w.	26	nw.	2	13	4	14	5.7	3.8	0.0
Detroit	730	218	258	29.03	29.84	−.19	34.4	+1.0	70	16	42	15	2	27	37	31	28	82	1.98	−0.4	14	8,143	w.	27	sw.	20	10	8	13	5.7	14.6	0.0
Upper Lake Region							29.4	+1.0										76	1.43	−0.7									5.6		
Alpena	609	13	92	29.14	29.83	−.20	26.6	+1.1	54	17	34	7	3	19	32	23	19	77	1.86	−0.1	15	8,731	nw.	34	nw.	20	5	12	14	6.2	17.3	1.0
Escanaba	612	54	60	29.18	29.87	−.17	24.9	+0.7	52	17	34	2	3	16	31	22	18	79	2.09	+0.2	10	7,827	nw.	39	n.	26	13	6	12	5.2	21.0	1.5
Grand Haven	632	54	89	29.15	29.85	−.18	32.2	+0.5	61	16	39	15	22	25	28	29	25	78	1.15	−1.2	10	9,621	nw.	36	w.	11	12	5	14	5.6	9.4	T.
Grand Rapids	707	70	87	29.08	29.87	−.16	33.6	+0.2	69	16	42	15	2	26	29	28	22	67	1.20	−1.3	9	5,521	nw.	25	sw.	31	12	6	13	5.2	14.3	T.
Houghton	668	64	99	29.12	29.87	−.17	24.3	+1.5	44	12	33	3	2	16	37	.....	.....	.....	1.15	−0.8	8	8,127	w.	44	w.	20	9	6	16	6.6	11.9	1.0
Lansing	878	6	49	28.88	29.84	.....	31.8	−0.4	69	16	40	13	22	23	37	28	26	55	1.47	−0.9	11	5,143	w.	26	nw.	12	12	8	11	5.3	16.0	T.
Ludington	637	60	66	29.14	29.85	.....	30.6	+0.5	54	16	37	14	2	24	24	28	24	79	1.84	−0.4	11	8,198	nw.	29	nw.	11	12	8	11	5.2	18.7	1.3
Marquette	734	77	111	29.04	29.86	−.18	26.4	+1.6	55	17	34	4	2	19	30	23	19	79	1.76	−0.5	13	7,831	nw.	37	nw.	11	8	8	15	6.3	17.9	4.7
Port Huron	638	70	120	29.11	29.82	−.21	32.0	+1.6	65	17	40	14	2	24	32	28	24	75	1.19	−0.9	10	8,729	w.	32	nw.	12	6	10	6	5.5	10.4	0.0
Sault Sainte Marie	614	11	52	29.13	29.85	−.18	23.2	+1.6	43	31	31	0	2	16	32	20	18	83	0.93	−0.9	16	7,185	nw.	45	nw.	13	7	13	11	5.8	8.6	2.5
Chicago	673	7	131	29.14	29.89	−.14	36.1	+0.8	73	16	43	15	2	29	28	31	25	68	2.82	+0.2	9	9,124	nw.	35	ne.	25	10	8	13	5.6	21.6	1.0
Green Bay	617	109	141	29.18	29.86	−.18	30.4	+1.8	66	16	38	7	3	23	27	26	21	70	0.72	−1.3	10	8,688	nw.	32	ne.	24	7	8	16	6.5	6.7	0.3
Milwaukee	681	125	221	29.12	29.87	−.16	33.8	+1.7	71	16	41	12	2	26	31	30	25	74	1.55	−0.9	11	10,550	w.	42	n.	25	14	7	10	5.2	12.2	T.
Duluth	1,133	5	47	28.65	29.92	−.14	25.0	+1.3	50	12	34	−10	2	16	33	21	14	68	0.30	−1.2	4	9,375	nw.	37	w.	12	15	7	9	4.6	3.0	0.0
North Dakota							26.4	+4.0										77	0.10	−0.7									4.7		
Moorhead	940	50	58	28.93	29.98	−.10	27.0	+4.3	60	19	35	−1	2	19	49	24	20	78	0.27	−0.7	6	7,316	n.	31	nw.	12	10	10	11	5.6	3.1	T.
Bismarck	1,674	8	57	28.17	30.02	−.04	28.0	+3.8	55	19	37	−3	2	18	49	24	20	74	T.	−0.9	0	7,126	nw.	34	nw.	12	12	12	7	4.5	T.	0.0
Devils Lake	1,478	11	44	28.36	29.98	−.07	23.4	+3.6	51	22	32	−7	2	14	44	21	18	83	0.13	−0.6	6	7,655	nw.	40	nw.	12	13	12	6	4.3	2.1	T.
Ellendale	1,457	10	56	28.38	29.98	.....	29.4	.....	60	19	39	−2	2	20	45	.....	.....	.....	0.03	−0.8	2	11,184	nw.	41	nw.	19	7	14	10	5.7	0.7	T.
Grand Forks	833	12	67	.....	.....	.....	24.0	.....	54	19	32	−3	20	16	49	22	.....	.....	0.43	.....	6	.....	nw.	42	sw.	12	20	10	1	.....	3.3	T.
Williston	1,878	41	48	27.99	30.04	.00	27.0	+4.1	54	22	38	−6	1	16	39	23	18	72	0.06	−0.6	1	5,635	w.	30	nw.	12	18	8	5	3.3	0.6	0.0
Upper Mississippi Valley							37.6	+1.5										65	1.12	−1.2									4.8		
Minneapolis	918	102	208	28.90	29.91	.....	31.6	+2.0	71	16	40	−2	2	23	34	.....	.....	.....	0.48	−0.9	5	9,367	nw.	34	nw.	11	13	6	12	5.5	1.8	0.0
St. Paul	837	236	261	29.00	29.93	−.12	31.9	+2.8	71	16	41	−2	2	23	34	.....	.....	.....	0.59	−0.8	7	9,409	nw.	35	nw.	11	11	10	10	5.9	4.0	0.0
La Crosse	714	11	48	29.11	29.90	−.14	34.0	+2.5	75	16	43	3	2	25	34	28	22	65	1.25	−0.4	8	4,064	nw.	18	nw.	11	9	10	12	5.7	8.1	3.0
Madison	974	70	78	28.82	29.90	−.14	32.9	+2.3	70	16	41	6	2	24	31	28	22	69	1.29	−0.8	7	7,529	nw.	34	ne.	25	13	8	10	4.9	5.9	T.
Wausau	1,247	4	64	28.51	29.88	.....	29.3	.....	68	16	38	4	3	20	32	.....	.....	.....	0.90	−0.8	5	5,319	n.	21	n.	25	12	7	12	5.6	8.6	T.
Charles City	1,015	10	51	28.84	29.95	−.10	33.8	+3.1	74	16	43	3	2	24	34	28	22	67	0.90	−0.9	7	6,042	nw.	25	w.	16	15	10	6	4.1	T.	T.
Davenport	606	71	79	29.24	29.92	−.11	38.4	+2.3	72	16	48	8	2	29	34	32	24	61	1.02	−1.3	4	9,532	nw.	38	nw.	26	12	10	9	4.9	0.5	0.0
Des Moines	861	5	99	29.02	29.95	−.09	38.1	+2.2	77	16	49	7	2	28	43	32	23	60	1.12	−0.7	4	9,073	nw.	37	nw.	11	12	10	9	5.1	0.7	0.0
Dubuque	700	81	96	29.14	29.91	−.13	35.6	+1.6	74	16	45	6	2	26	35	30	25	69	1.23	−0.8	8	6,072	nw.	26	n.	25	13	9	9	5.1	5.4	T.
Keokuk	614	64	78	29.26	29.95	−.08	40.0	+1.1	73	16	50	11	2	30	37	32	23	55	0.67	−1.7	4	7,237	w.	30	nw.	11	13	6	12	5.1	0.2	0.0
Cairo	358	87	93	29.56	29.94	−.10	46.8	−0.4	71	15	56	22	2	38	39	40	34	67	2.54	−1.2	7	7,284	s.	29	nw.	11	10	9	12	5.2	0.3	0.0
Peoria	609	11	45	29.39	29.92	−.11	38.7	+1.7	72	16	49	12	2	28	33	32	26	67	1.55	−1.2	5	6,580	w.	26	w.	1	18	8	5	3.7	5.6	0.0
Springfield, Ill	636	154	191	29.23	29.92	−.11	39.2	−1.0	70	16	49	12	2	30	34	34	29	72	1.17	−2.0	7	10,808	w.	42	nw.	11	9	13	9	4.9	5.1	T.
Hannibal	534	74	109	29.35	29.94	−.08	41.1	+0.1	71	16	51	14	2	31	40	.....	.....	.....	0.94	−1.7	5	7,983	nw.	29	nw.	11	12	13	6	4.3	1.0	0.0
St. Louis	568	265	303	29.31	29.93	−.10	44.4	+0.6	70	20	54	18	2	35	33	37	28	58	0.99	−2.4	5	9,967	nw.	46	w.	26	15	9	7	3.9	1.5	0.0
Missouri Valley							38.9	+1.4										60	0.61	−1.2									4.1		
Columbia, Mo	784	6	84	29.10	29.95	−.08	42.8	+0.2	72	16	53	13	2	32	42	.....	.....	.....	1.03	−1.9	6	7,478	nw.	35	nw.	11	14	8	9	4.7	3.7	0.0
Kansas City	963	161	181	28.92	29.97	−.05	43.6	+0.9	75	12	54	12	2	33	36	35	25	54	0.67	−1.9	4	9,741	nw.	40	nw.	11	19	7	5	3.3	T.	0.0
St. Joseph	967	11	49	28.90	29.96	.....	42.6	.....	76	12	54	11	2	31	43	33	23	53	0.83	−1.2	3	8,029	nw.	33	nw.	11	21	7	3	2.7	0.1	0.0
Springfield, Mo	1,324	98	104	28.55	29.98	−.04	44.3	−0.9	68	20	54	14	2	34	34	36	27	58	0.77	−2.6	5	8,502	nw.	38	nw.	11	21	5	5	3.0	0.5	0.0
Iola	984	11	50	28.92	29.99	−.02	44.4	−0.1	76	12	58	12	2	31	45	.....	.....	.....	0.16	−2.5	3	5,720	nw.	22	n.	25	18	7	6	3.9	T.	0.0
Topeka	987	92	107	.....	.....	.....	43.2	+0.6	77	12	55	12	2	32	41	.....	.....	.....	0.55	−1.6	2	8,501	nw.	35	nw.	11	17	8	6	3.7	T.	0.0
Lincoln	1,189	11	81	28.69	29.98	−.04	39.7	+2.2	78	16	51	8	2	28	41	32	23	58	0.58	−0.7	5	8,749	nw.	34	nw.	10	15	9	7	3.9	T.	0.0
Omaha	1,105	115	122	28.78	29.99	−.05	39.4	+2.4	79	16	50	6	2	29	41	32	21	53	0.65	−0.7	4	7,656	nw.	33	nw.	11	17	9	5	3.4	0.7	0.0
Valentine	2,598	47	54	27.25	30.04	+.01	32.8	+0.5	71	15	44	0	3	21	41	27	22	70	1.04	0.0	11	6,183	n.	30	nw.	6	13	7	11	5.0	10.2	2.0
Sioux City	1,135	94	164	28.75	30.00	−.05	36.4	+3.7	74	16	47	3	2	26	40	29	21	60	0.12	−1.0	4	10,343	nw.	42	nw.	10	10	10	11	5.2	0.5	0.1
Huron	1,306	59	74	28.58	30.01	−.05	32.0	+3.1	68	15	42	−3	2	22	40	27	22	71	0.09	−0.2	7	7,350	nw.	28	w.	2	13	10	8	4.7	3.7	0.0
Pierre	1,572	70	75	28.32	30.04	−.01	33.0	+1.5	68	19	42	4	2	24	43	28	20	65	0.49	−0.4	4	6,688	nw.	31	n.	19	14	9	8	4.5	1.9	0.0
Yankton	1,233	49	57	28.65	30.00	−.05	35.5	+2.3	72	15	46	2	2	25	38	.....	.....	.....	0.41	−0.9	6	6,995	nw.	24	nw.	1	11	12	8	5.0	2.6	T.

TABLE 1.—*Climatological data for weather bureau stations, March, 1930*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	° *F.*	° *F.*	°F.		°F.	°F.		°F.	° *F.*	° *F.*	° *F.*	%	° *F.*	*In.*	*In.*		*Miles*							*0–10*	*In.*	*In.*
Northern Slope							**31.4**	**+0.1**											**66**	**0.76**	**−0.2**									**5.6**		
Billings	3,140	5					33.6		64	19	47	−16	2	20	42					0.53		8		nw.				8	6	17		3.7	
Havre	2,505	11	44	27.35	30.06	+0.06	29.6	+2.5	62	11	41	−8	20	18	45	25	20	71		0.58	+0.1	9	5,093	sw.	32	sw.	11	6	13	12	6.0	7.3	0.0
Helena	4,124	89	113	25.77	30.08	+.07	30.4	−2.0	59	11	40	−12	2	20	42	26	20	66		1.06	+0.3	15	5,207	sw.	21	sw.	3	12	16	7.1	16.5	0.0
Kalispell	2,973	48	56	26.91	30.03	[1]	34.0	+1.1	57	11	42	−2	2	26	29	29	22	65		0.35	−0.6	7	4,305	nw.	26	w.	19	8	13	10	5.7	1.8	0.0
Miles City	2,371	48	55	27.47	30.08	[1]	33.4	+4.8	63	19	45	−1	2	22	57	27	19	60		0.29	−0.6	4	4,639	n.	29	nw.	23	10	13	8	4.8	1.9	0.0
Rapid City	3,259	50	58	26.56	30.07	+.06	32.7	+0.1	63	19	43	−3	2	22	43	27	20	63		0.97	0.0	11	6,021	n.	30	n.	6	12	8	11	5.1	3.9	0.0
Cheyenne	6,088	84	101	23.90	30.02	+.08	29.6	−3.5	58	16	40	−8	2	19	43	25	19	65		0.88	−0.1	9	9,688	w.	49	w.	19	10	10	11	5.4	9.7	1.8
Lander	5,372	60	68	24.56	30.02	+.03	30.8	−1.6	59	11	43	−9	3	19	42	27	23	76		1.30	+0.1	9	3,491	sw.	37	nw.	23	16	9	6	4.2	11.2	2.0
Sheridan	3,790	10	47	26.06	30.05		31.4		63	19	43	−9	2	20	48	27	20	65		0.73	−0.4	9	3,615	nw.	29	nw.	23	8	10	13	5.7	6.5	0.0
Yellowstone Park	6,241	11	48	23.80	30.07	+.05	25.8	−0.7	47	15	36	−13	2	16	43	22	17	68		1.10	−0.6	14	5,612	sw.	27	sw.	19	3	13	15	7.2	18.3	T.
North Platte	2,821	11	51	27.02	30.01	+.01	36.5	−0.1	73	15	50	6	2	23	44	28	19	59		0.29	−0.6	1	6,169	n	28	n.	6	14	9	8	4.3	3.0	0.0
Middle Slope							**41.7**	**−1.6**											**53**	**0.30**	**−1.3**									**4.3**		
Denver	5,292	106	113	24.65	29.99	+.04	37.2	−2.1	69	15	49	7	2	26	39	29	17	52		0.44	−0.6	10	5,413	s.	35	w.	23	9	13	9	5.4	8.3	1.0
Pueblo	4,685	80	86	25.19	29.93	+.01	38.4	−3.2	72	16	53	10	3	24	47	30	18	51		0.56	0.0	5	4,459	nw.	32	w.	5	11	12	8	4.9	5.3	0.0
Concordia	1,392	50	58	28.52	30.02	+.01	40.4	−0.6	75	12	53	10	2	28	44	32	22	54		0.24	−1.0	4	7,186	nw.	29	nw.	1	14	13	4	4.2	0.8	0.0
Dodge City	2,509	11	51	27.38	30.03	+.06	41.2	−1.6	77	12	56	7	3	26	52	32	21	53		0.07	−0.8	2	6,845	nw.	29	nw.	7	20	9	2	2.7	T.	0.0
Wichita	1,358	139	158	28.52	29.98	−.01	44.0	−1.1	76	12	56	16	2	33	38	36	24	53		0.22	−1.5	2	9,179	n.	40	s.	31	16	7	8	4.2	T.	0.0
Broken Arrow	765	11	56	29.15	29.99		47.5		73	6	58	20	2	36	33					0.35	−3.5	3	10,248	nw.	37	sw.	31	12	13	6	4.5	T.	0.0
Oklahoma City	1,214	10	47	28.69	29.99	+.01	48.8	−1.2	75	6	61	21	3	37	36	39	29	53		0.25	−1.7	3	7,743	s.	31	n.	7	16	9	6	4.0	T.	0.0
Southern Slope							**51.5**	**−3.9**											**50**	**1.17**	**+0.3**									**4.5**		
Abilene	1,738	10	52	28.17	30.00	+.04	54.2	−2.3	83	17	67	23	3	41	44	42	28	47		0.97	−0.3	5	7,181	s.	31	w.	6	11	7	13	5.2	1.7	0.0
Amarillo	3,676	10	49	26.22	29.98	+.03	44.7	−2.2	73	22	57	17	2	32	46	35	24	55		1.27	+0.6	4	5,863	n.	25	w.	6	14	10	7	4.0	3.9	0.0
Del Rio	944	64	71	28.98	29.97	+.02	59.7	−3.8	89	6	70	34	4	49	37	49	39	54		1.48	+0.8	5	6,567	se.	33	nw.	6	11	10	10	5.2	0.0	0.0
Roswell	3,566	75	85	26.31	29.94	+.04	47.4	−3.9	80	31	63	18	2	32	52	36	21	42		0.96	+0.2	4	6,038	s.	36	nw.	6	19	6	6	3.5	0.9	0.0
Southern Plateau							**50.4**	**−0.4**											**45**	**0.78**	**+0.3**									**3.4**		
El Paso	3,778	152	175	26.13	29.92	+.04	53.3	−2.5	78	31	65	29	2	41	38	39	21	33		0.03	−0.3	2	7,417	nw.	38	nw.	6	19	9	3	3.2	0.0	0.0
Santa Fe	7,013	38	53	23.14	29.92	+.03	37.2	−2.5	61	22	48	11	1	26	32	29	18	50		0.68	−0.1	7	4,319	n.	21	nw.	23	14	9	8	4.4	2.2	0.0
Flagstaff	6,907	10	59	23.26	29.89	−.02	35.4	−0.5	64	25	48	−6	1	23	41	29		63		2.41		5	5,625	nw.	33	sw.	15	11	14	6		15.0	T.
Phoenix	1,108	10	107	28.74	29.90	−.01	60.6	−0.1	85	26	74	37	1	47	36	47	32	42		1.77	+1.1	5	3,715	e.	25	sw.	15	19	4	8	3.4	0.0	0.0
Yuma	141	9	54	29.76	29.92	−.02	64.2	+0.1	92	25	78	42	1	50	39	50	33	39		0.91	+0.6	2	4,153	n.	29	se.	15	22	5	4	2.4	0.0	0.0
Independence	3,957	6	27	25.92	29.96	+.02	51.4	+2.9	82	25	65	22	1	38	36					0.53	0.0	4		nw.				18	7	6		1.0	0.0
Middle Plateau							**42.2**	**+1.3**											**54**	**0.54**	**−0.6**									**4.1**		
Reno	4,532	74	81	25.44	29.99	+.01	44.1	+3.1	73	25	57	17	1	31	40	36	26	55		0.55	−0.3	7	3,929	w.	30	w.	29	18	8	5	3.4	2.1	0.0
Tonopah	6,090	12	20				41.2		66	29	51	17	1	31	28	33	24	55		0.68		3		nw.									
Winnemucca	4,344	18	56	25.60	30.02	+.01	41.7	+1.7	72	29	55	17	1	28	43	34	25	59		0.68	−0.3	5	4,679	ne.	29	nw.	30	16	13	2	3.2	2.5	0.0
Modena	5,473	10	43	24.54	29.91	−.05	39.4	+1.2	68	25	53	6	1	26	41	33	24	58		0.39	−0.6	6	7,078	w.	35	s.	30	12	9	10	4.5	T.	0.0
Salt Lake City	4,360	163	203	25.57	29.97	−.01	42.8	+1.1	63	21	51	24	1	35	27	36	27	54		0.74	−1.2	10	4,943	nw.	33	w.	5	11	13	7	4.9	4.0	0.0
Grand Junction	4,602	60	68	25.32	29.91	−.03	42.8	−0.8	66	15	54	18	1	32	31	34	21	46		0.36	−0.4	5	4,261	se.	26	nw.	23	13	9	9	4.5	0.4	0.0
Northern Plateau							**43.3**	**+1.8**											**58**	**0.94**	**−0.4**									**5.7**		
Baker	3,471	48	53	26.45	30.07	+.04	40.0	+2.4	65	28	50	18	1	30	34	35	27	61		0.17	−0.9	7	4,277	se	23	sw	21	8	12	11	6.0	0.2	0.0
Boise	2,739	78	86	27.16	30.05	+.02	44.3	+1.6	70	29	54	24	2	34	32	37	28	59		1.59	+0.2	4	3,688	se.	22	se.	30	9	7	15	6.3	5.7	0.0
Lewiston	757	40	48	29.25	30.07	+.04	47.0	+1.6	74	28	57	30	2	37	36					1.41	+0.3	8	2,741	e.	23	nw.	12	10	11	10	5.7	0.0	0.0
Pocatello	4,477	60	68	25.43	30.00	−.01	38.8	+1.4	61	29	48	8	2	30	31	33	25	59		0.53	−0.8	10	6,177	sw.	34	s.	29	8	14	9	5.2	0.7	0.0
Spokane	1,929	101	110	27.98	30.06	+.05	42.1	+2.4	70	28	52	20	2	32	33	36	27	57		0.71	−0.5	5	4,287	s.	27	sw.	22	10	11	10	5.4	T.	0.0
Walla Walla	991	57	65	28.98	30.06	+.04	47.6	+1.5	73	28	56	26	2	39	28	41	31	55		1.24	−0.4	8	3,700	s.	27	w.	22	11	7	13	5.7	T.	0.0
North Pacific Coast Region							**47.5**	**+2.5**											**69**	**2.10**	**−1.4**									**5.9**		
North Head	211	11	56	29.88	30.11	+.10	46.6	+1.4	66	28	51	34	14	42	18	43	40	79		3.78	−1.8	12	10,848	n.	50	s.	21	12	4	15	5.8	0.0	0.0
Port Angeles	29	8	53		30.11		43.8		66	28	51	28	15	36	23					1.96	−0.2	12	3,883	sw.	35	nw.	19	5	9	17		0.2	0.0
Seattle	125	215	250	29.95	30.08	+.09	46.8	+1.9	68	28	53	34	13	40	24	42	36	69		1.86	−1.2	12	5,759	n.	38	sw.	21	8	9	14	6.4	T.	0.0
Tacoma	194	172	201	29.88	30.10	+.10	46.8	+2.6	68	28	54	33	1	40	26					2.47	−1.0	9	6,078	n.	34	sw.	19	8	9	14	6.0	0.0	0.0
Tatoosh Island	86	9	53	29.98	30.07	+.11	45.2	+2.3	61	30	49	33	13	41	17	43	40	84		4.99	−2.9	15	11,010	e.	48	e.	2	10	4	17	6.4	0.3	0.0
Yakima	1,076	58	67	28.90	30.06		47.7	+3.6	80	28	59	28	2	36	39	39	27	49		0.20	−0.2	6	4,159	nw.	32	w.	21	14	10	7	4.7	0.0	0.0
Medford	1,329	29	58	28.51	30.02		49.4		86	28	64	25	1	35	46	44	40	73		0.49	−1.2	4		se.	36	se.	3	11	7	13	5.5	T.	0.0
Portland, Oreg	153	68	106	29.93	30.09	+.07	50.3	+3.4	83	28	59	33	1	42	32	44	36	64		2.21	−1.7	8	4,449	nw.	23	e.	2	9	6	16	6.2	0.0	0.0
Roseburg	510	75	99	29.52	30.07	+.03	49.2	+2.1	82	28	61	26	1	38	38	44	37	67		0.90	−2.4	6	2,424	n.	22	n.	30	8	11	12	5.9	0.0	0.0
Middle Pacific Coast Region							**55.4**	**+2.6**											**71**	**2.99**	**−0.4**									**4.0**		
Eureka	62	73	89	29.99	30.06	.00	50.5	+2.2	78	27	57	34	1	44	26	47	44	80		1.23	−4.0	7	4,119	n.	32	s.	3	11	6	14	5.3	0.0	0.0
Red Bluff	330	5	58	29.62	29.98	−.06	57.4	+3.8	88	25	70	32	1	45	39	49	40	58		4.38	+1.1	7	4,565	nw.	24	se.	3	18	6	7	3.7	0.0	0.0
Sacramento	69	106	117	29.90	29.97	−.06	56.3	+2.0	81	26	66	37	1	46	34	51	46	72		2.86	+0.3	7	5,272	se.	24	se.	3	22	6	3	2.5	0.0	0.0
San Francisco	155	208	243	29.81	29.98	−.08	57.4	+3.2	82	26	64	44	15	51	25	51	47	73		3.53	+0.4	6	4,891	w.	26	se.	4	13	13	5	3.9	0.0	0.0
San Jose	141	12	110	29.84	29.99		55.6	+1.9	84	25	67	33	1	44	38					2.93	+0.3	6	4,072	nw.	29	s.	4	11	14	6	4.5	0.0	0.0
South Pacific Coast Region							**59.2**	**+2.8**											**67**	**2.80**	**+0.8**									**4.3**		
Fresno	327	89	98	29.63	29.99	−.02	57.2	+2.2	83	28	68	36	1	46	29	50	44	66		1.38	−0.2	5	3,709	nw.	19	se.	3	21	9	1	2.6	0.0	0.0
Los Angeles	338	159	191	29.61	29.98	−.04	60.8	+3.3	89	24	69	41	15	53	29	52	44	63		3.99	+1.2	7	3,853	ne.	24	se.	14	13	10	8	4.7	0.0	0.0
San Diego	87	62	70	29.87	29.97	−.05	59.6	+2.9	82	24	67	43	15	52	26	53	49	72		3.02	+1.3	10	4,235	w.	32	s.	14	11	8	12	5.5	0.0	0.0
West Indies																																	
San Juan, P. R	82	9	54	29.90	29.99		75.8	+0.4	88	25	82	65	3	70	19					1.75	−1.4	9	7,530	e.	37	e.	28	10	18	3	4.5	0.0	0.0
Panama Canal																																	
Balboa Heights	118	7	97	[1] 29.75	[2] 29.83	−.01	82.0	+0.8	93	30	91	70	19	73	23				[2] 73	0.01	−0.7	1	7,075	nw.	24	n.	1	3	23	5	6.2	0.0	0.0
Cristobal	38	7	97	[1] 29.82	[2] 29.85	−.03	82.0	+0.5	88	10	86	73	19	78	12	75	73	[2] 76		1.07	−0.4	13	9,450	n.	25	n.	13	8	16	7	5.3	0.0	0.0
Alaska																																	
Fairbanks	455	11	44	[1] 29.35	[1] 29.91		6.6		47	27	19	−44	18	−6	54	5	1	75		0.73		15		se.				4	8	19	7.4	11.8	10.0
Juneau	80	11	50	[1] 29.89	[1] 29.98		32.0		48	27	37	2	18	27	20	30	27	79		10.12		24	5,367	e.	27	nw.	17	1	7	23	8.7	16.7	0.0
Hawaiian Islands																																	
Honolulu	38	86	100	[1] 29.98	[1] 30.02		71.2	−0.2	80	19	76	57	12	67	16	65	61	71		2.08	−1.1	15	7,430	e.	32	e.	2	12	7	12	5.0	0.0	0.0

[1] Pressure not reduced to mean of 24 hours.

[2] Observations taken bi-hourly.

TABLE 2.—*Data furnished by the Canadian Meteorological Service, March, 1930*

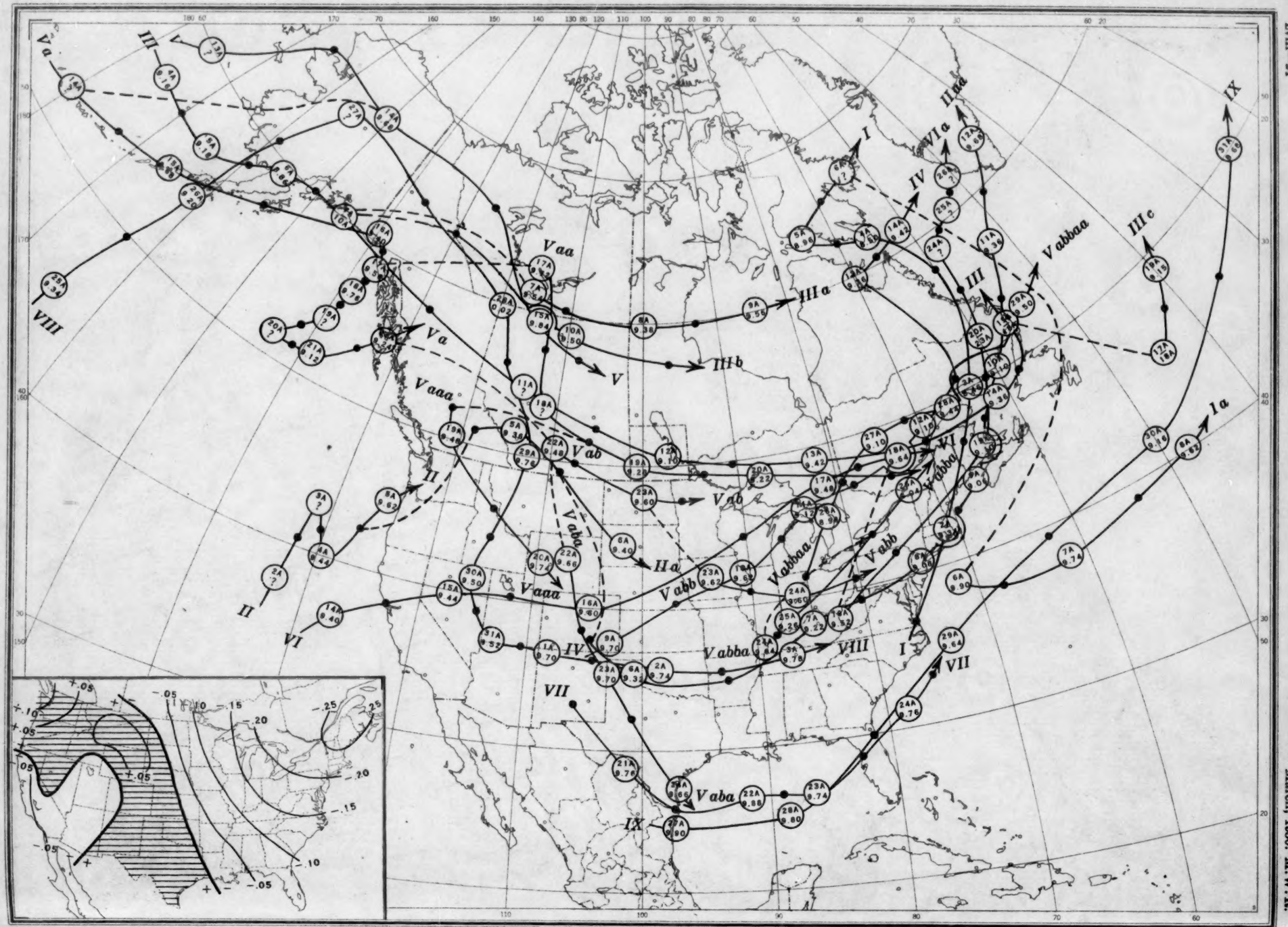
Stations	Altitude above mean sea level Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*Inches*	*Inches*	*Inches*	°F.	°F.	°F.	°F.	°F.	°F.	*Inches*	*Inches*	*Inches*
Cape Race, N. F.	99				29.3		35.5	23.1	40	0	2.75		10.8
Sydney, C. B. I.	48	29.64	29.69	−0.19	30.9	+4.7	38.5	23.4	48	10	3.89	−1.04	3.5
Halifax, N. S.	88	29.58	29.69	−.25	32.2	+3.2	39.9	24.5	50	9	5.06	−0.40	3.1
Yarmouth, N. S.	65	29.57	29.64	−.31	33.5	+2.7	39.5	27.4	55	10	4.34	−0.66	0.2
Charlottetown, P. E. I.	38	29.54	29.58	−.32	29.2	+3.8	35.6	22.8	47	6	2.42	−0.79	7.8
Chatham, N. B.	28	29.50	29.53	−.37	25.5	+2.5	33.7	17.3	49	−9	3.12	−0.35	7.4
Father Point, Que.	20	29.62	29.64	−.26	24.0	+3.7	29.9	18.1	44	2	5.33	+2.60	52.8
Quebec, Que.	296	29.38	29.71	−.25	23.2	+2.0	29.5	16.8	40	−4	3.58	+0.32	32.4
Doucet, Que.	1,236				10.0		24.3	−4.1	44	−34	2.90		29.0
Montreal, Que.	187	29.52	29.74	−.26	26.3	+2.5	32.6	20.0	43	1	2.54	−1.25	12.3
Ottawa, Ont.	236	29.50	29.77	−.24	27.6	+6.1	35.2	20.0	47	2	1.85	−0.87	9.1
Kingston, Ont.	285	29.46	29.78	−.23	29.2	+3.6	35.4	23.0	47	7	2.93	+0.29	4.3
Toronto, Ont.	379	29.38	29.81	−.21	31.1	+3.8	37.3	24.8	51	15	3.20	+0.56	10.5
Cochrane, Ont.	930				15.3		25.3	5.4	43	−15	3.03		27.0
White River, Ont.	1,244	28.46	29.82	−.21	13.8	+1.6	27.9	−0.2	41	−33	2.16	+0.78	19.6
London, Ont.	808				31.0		39.0	23.1	64	13	3.28		23.0
Southampton, Ont.	656	29.06	29.79	−.24	27.1	+2.4	34.2	20.1	54	9	1.82	−0.83	14.2
Parry Sound, Ont.	688	29.07	29.79	−.23	24.0	+2.9	31.1	16.9	45	5	1.81	−0.42	11.0
Port Arthur, Ont.	644	29.17	29.90	−.15	22.7	+5.9	30.7	14.7	43	−6	0.98	+0.01	8.3
Winnipeg, Man.	760												
Minnedosa, Man.	1,690	28.11	30.00	−.06	18.0	+5.5	28.5	7.4	38	−17	1.63	+0.98	16.3
Le Pas, Man.	860				14.5		27.8	1.3	43	−27	0.68		6.8
Qu'Appelle, Sask.	2,115	27.68	30.01	−.03	19.3	+4.4	28.5	10.1	42	−20	0.63	−0.14	6.3
Moose Jaw, Sask.	1,759				25.0		35.7	14.3	52	−10	0.48		4.2
Swift Current, Sask.	2,392	27.38	29.97	−.05	28.1	+6.1	39.2	17.0	59	−8	0.19	−0.62	1.9
Medicine Hat, Alb.	2,144												
Calgary, Alb.	3,428												
Banff, Alb.	4,521												
Prince Albert, Sask.	1,450	28.43	30.07	−.01	18.4	+6.4	31.1	5.7	50	−21	1.26	+0.49	11.4
Battleford, Sask.	1,592	28.23	30.03	−.03	25.2	+12.1	37.2	13.2	53	−12	0.32	−0.14	2.2
Edmonton, Alb.	2,150												
Kamloops, B. C.	1,262												
Victoria, B. C.	230	29.83	30.09	+.12	45.4	+3.5	51.2	39.7	66	32	2.25	−0.87	0.1
Barkerville, B. C.	4,180												
Estevan Point, B. C.	20												
Prince Rupert, B. C.	170												
Hamilton, Ber.	151												
LATE REPORTS, FEBRUARY, 1930													
Cape Race, N. F.	99				23.9		32.3	15.4	42	3	4.34		7.3
Chatham, N. B.	28	29.84	29.88	−0.08	13.4	+0.9	26.0	0.8	44	−26	2.28	−0.88	8.8
Winnipeg, Man.	760	29.07	29.94	−.16	12.1	+13.7	18.9	5.4	43	−29	1.53	+0.55	14.1
Medicine Hat, Alb.	2,144	27.49	29.78	−.27	32.1	+20.9	41.9	22.3	60	−12	0.10	−0.57	1.0
Calgary, Alb.	3,428	26.20	29.84	−.15	28.5	+15.0	38.5	18.6	62	−12	0.33	−0.30	3.3
Banff, Alb.	4,521	25.19	29.88	−.10	24.5	+5.3	32.6	16.4	46	−17	1.13	+0.21	6.0
Edmonton, Alb.	2,150	27.45	29.79	−.23	21.9	+13.6	31.6	12.3	50	−24	0.14	−0.53	1.4
Kamloops, B. C.	1,262	28.62	29.94	−.02	33.9	+5.6	41.0	26.8	55	6	0.76	−0.03	2.5
Estevan Point, B. C.	20				39.5		45.2	33.8	48	27	15.98		4.6
Prince Rupert, B. C.	170				37.6		42.0	33.2	49	25	9.30		12.7

Chart I. Departure (°F.) of the Mean Temperature from the Normal, March, 1930

Chart I. Departure (°F.) of the Mean Temperature from the Normal, March, 1930

Chart II. Tracks of Centers of Anticyclones, March, 1930. (Inset) Departure of Monthly Mean Pressure from Normal

(Plotted by Welby R. Stevens)



Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time)

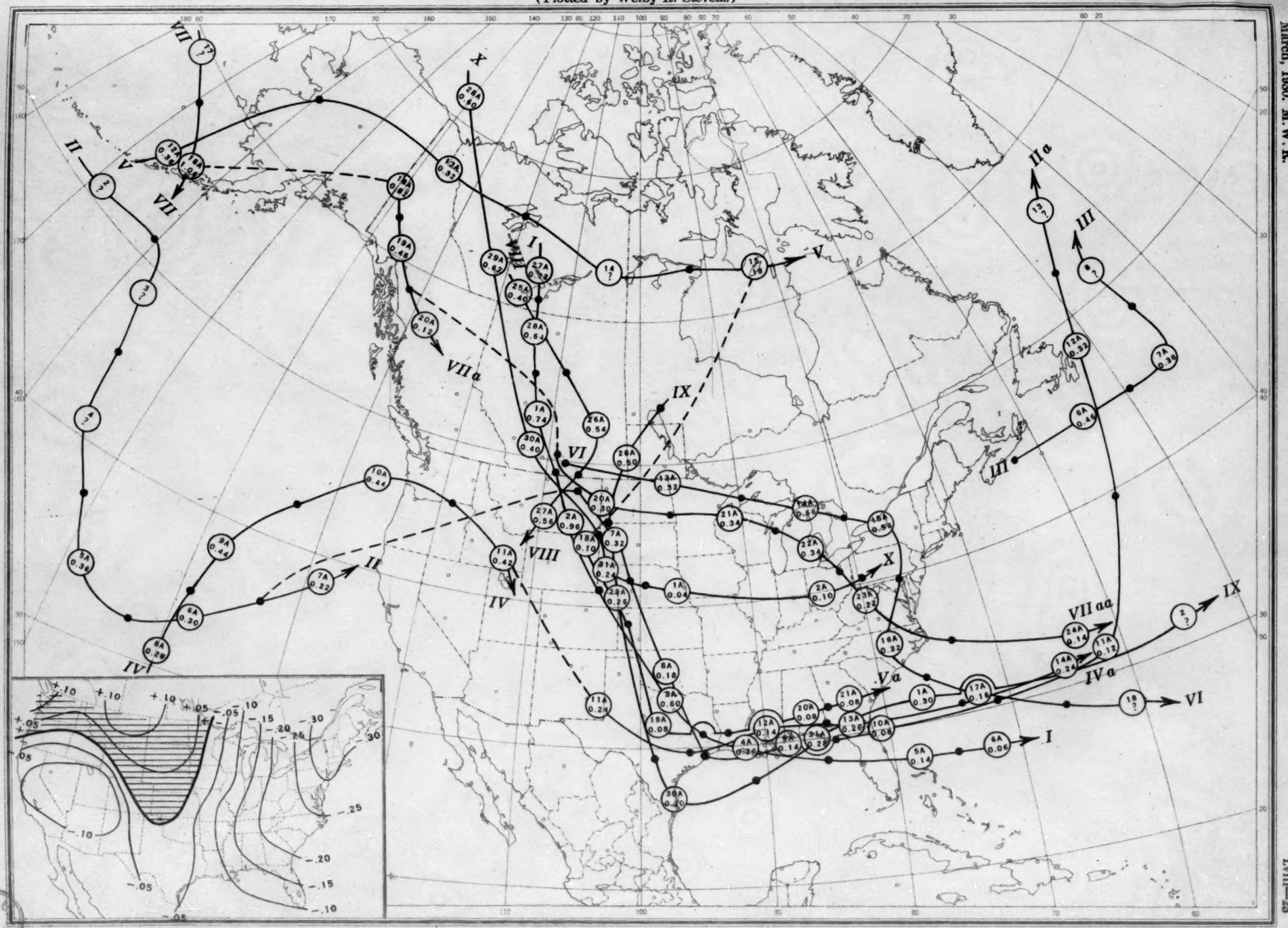
Chart III. Tracks of Centers of Cyclones, March, 1930. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by Welby R. Stevens)

Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time)

Chart III. Tracks of Centers of Cyclones, March, 1930. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by Welby R. Stevens)



Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky between Sunrise and Sunset, March, 1930

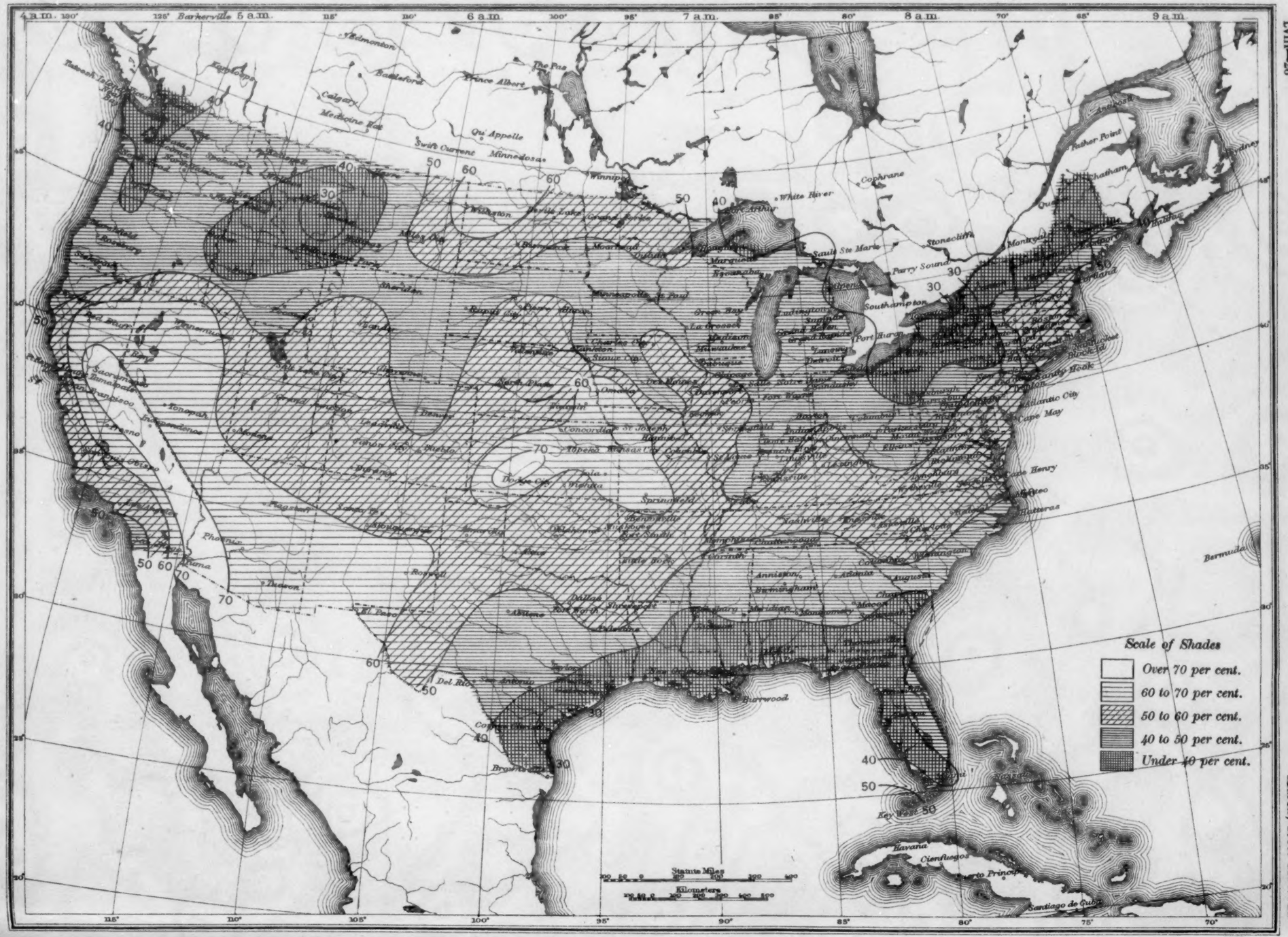


Chart V. Total Precipitation, Inches, March, 1930. (Inset) Departure of Precipitation from Normal

Chart V. Total Precipitation, Inches, March, 1930. (Inset) Departure of Precipitation from Normal

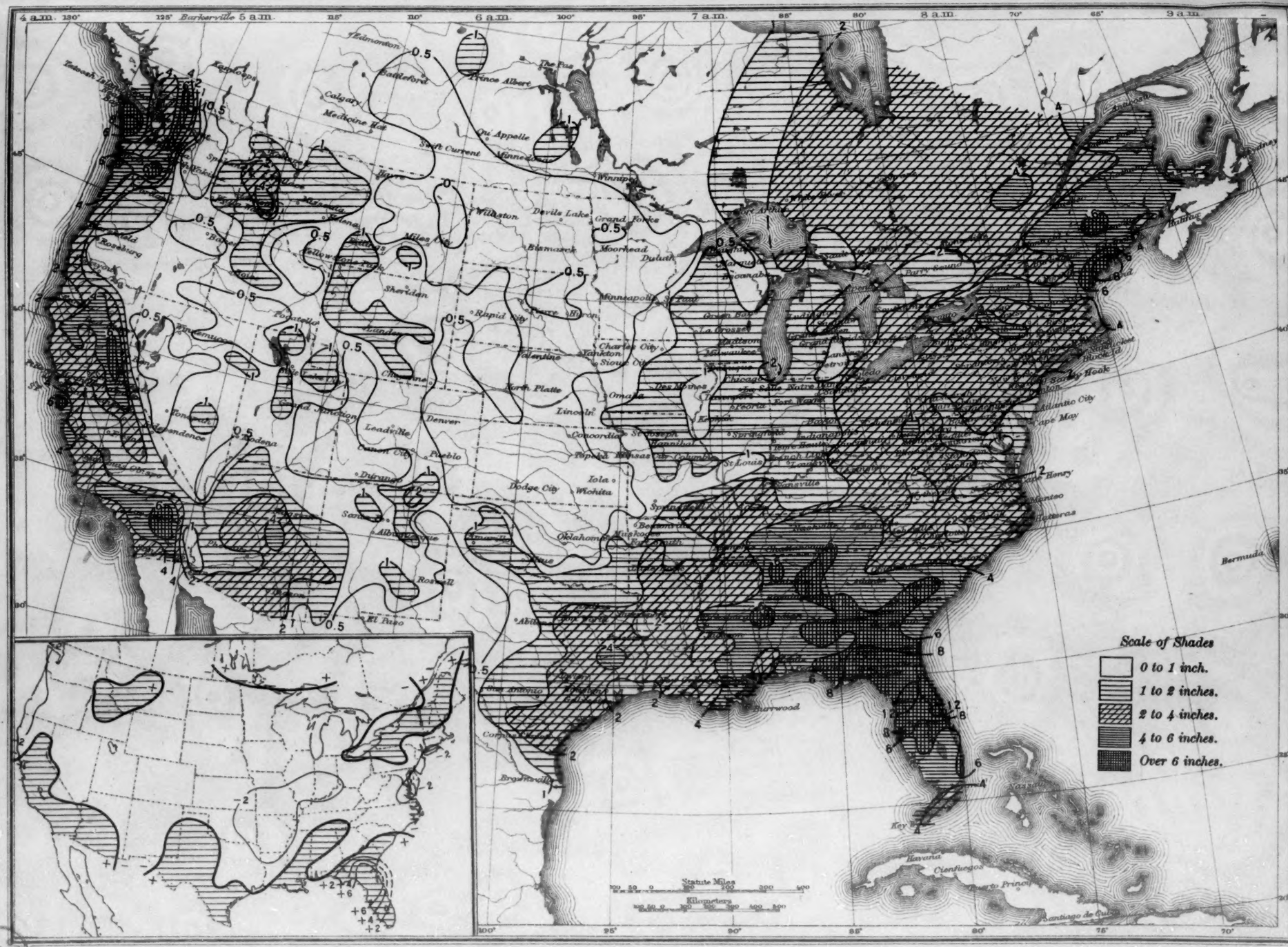


Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, March, 1930

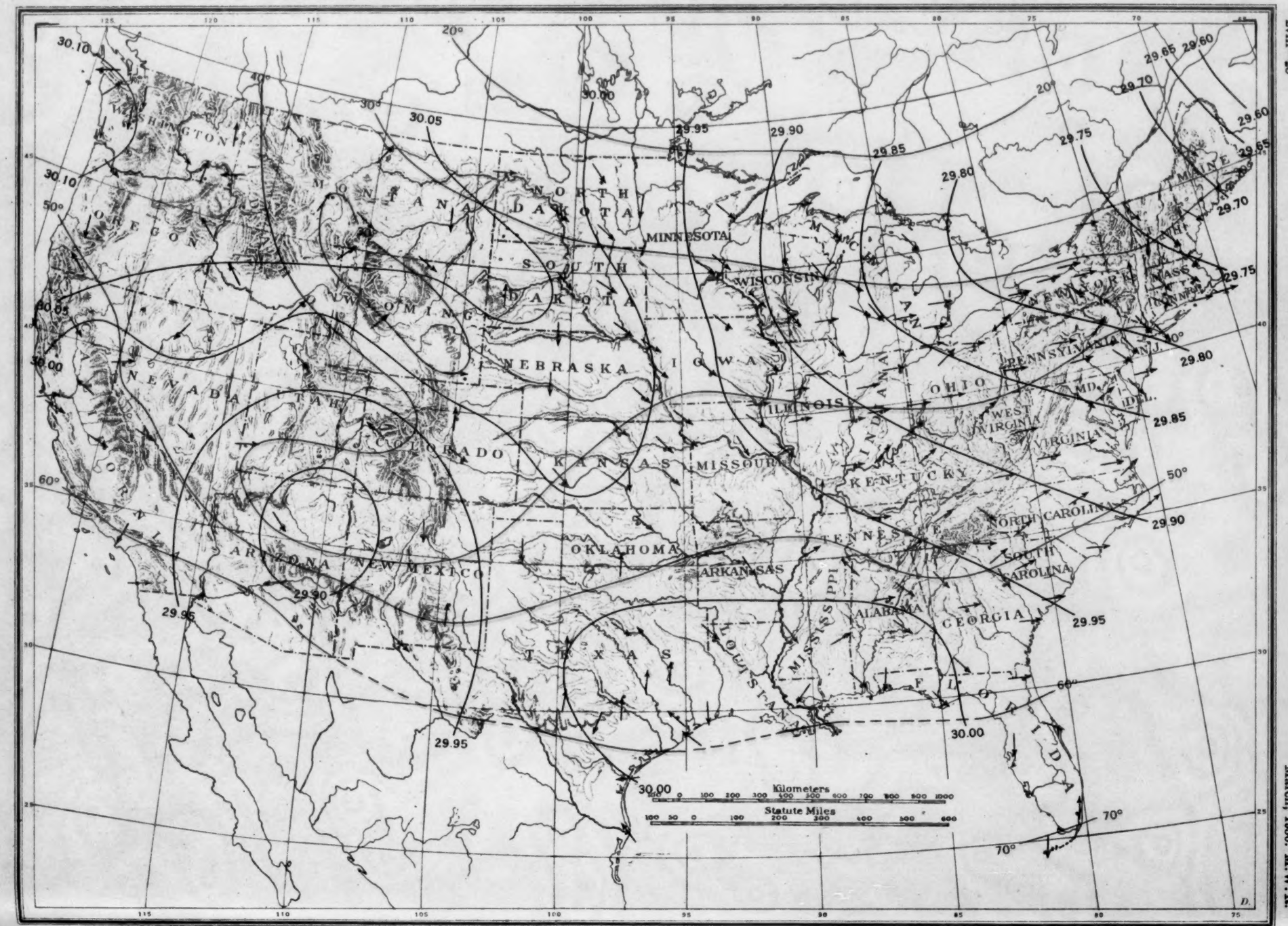


Chart VII. Total Snowfall, Inches, March, 1930. (Inset) Depth of Snow on Ground at end of Month

Chart VII. Total Snowfall, Inches, March, 1930. (Inset) Depth of Snow on Ground at end of Month

4 a.m.
5 a.m.
6 a.m.
7 a.m.
8 a.m.
9 a.m.
Barkerville
Edmonton
Kamloops
Banff
Prince Albert
The Pas
Calgary
Medicine Hat
Qu'Appelle
Swift Current
Minnedosa
Winnipeg
Cochrane
White River
Port Arthur
Sault Ste Marie
Stonecliffe
Parry Sound
Quebec
Father Point
Portland
Spokane
Lewiston
Wallace
Missoula
Helena
Billings
Miles City
Bismarck
Williston
Devils Lake
Grand Forks
Minneapolis
St. Paul
Rapid City
Pierre
Huron
Yankton
Sioux City
Omaha
Des Moines
Chicago
Detroit
Toledo
Cleveland
Buffalo
Albany
Boston
New York
Atlantic City
May
Baker
Winnemucca
Pocatello
Salt Lake City
Modena
Tonopah
Independence
Reno
Carson
Grand Junction
Denver
Leadville
Canon City
Pueblo
Dodge City
Wichita
Topeka
Kansas City
Concordia
Lincoln
North Platte
Springfield
Bentonville
Fort Smith
Oklahoma
Muskogee
Amarillo
Altus
Little Rock
Memphis
Chattanooga
Nashville
Louisville
Cairo
Evansville
Indianapolis
Cincinnati
Columbus
Parkersburg
Huntington
Charleston
Lynchburg
Norfolk
Asheville
Raleigh
Wilmington
Hatteras
Cape Henry
Manteo
Bermuda
Flagstaff
Santa Fe
Albuquerque
Phoenix
Yuma
El Paso
Roswell
Abilene
Fort Worth
Dallas
Shreveport
Palestine
Jackson
Vicksburg
Meridian
Montgomery
Macon
Savannah
Atlanta
Augusta
Columbia
Charlotte
Greensboro
Roanoke
Lynchburg
Harrisburg
Philadelphia
Baltimore
Washington
Pittsburgh
Erie
Toledo
Detroit
Cleveland
Buffalo
Rochester
Albany
Syracuse
Utica
Boston
Portland
Concord
Burlington
Montreal
Ottawa
Toronto
Kingston
Oswego
Rochester
Buffalo
Erie
Pittsburgh
Scranton
Wilkesbarre
Harrisburg
Philadelphia
Atlantic City
New York
Sandy Hook
Block Island
Nantucket
Provincetown
Portland
Eastport
Father Point
Quebec
Parry Sound
Stonecliffe
Sault Ste Marie
White River
Port Arthur
Cochrane
Winnipeg
Minnedosa
Qu'Appelle
Swift Current
Medicine Hat
Calgary
Banff
Prince Albert
The Pas
Edmonton
Barkerville
Kamloops
Victoria
Seattle
Tacoma
Portland
Astoria

Chart VIII. Weather Map of North Atlantic Ocean, March 1, 1930
(Plotted by E. A. Yeager)

Chart VIII. Weather Map of North Atlantic Ocean, March 1, 1930

(Plotted by F. A. Young)

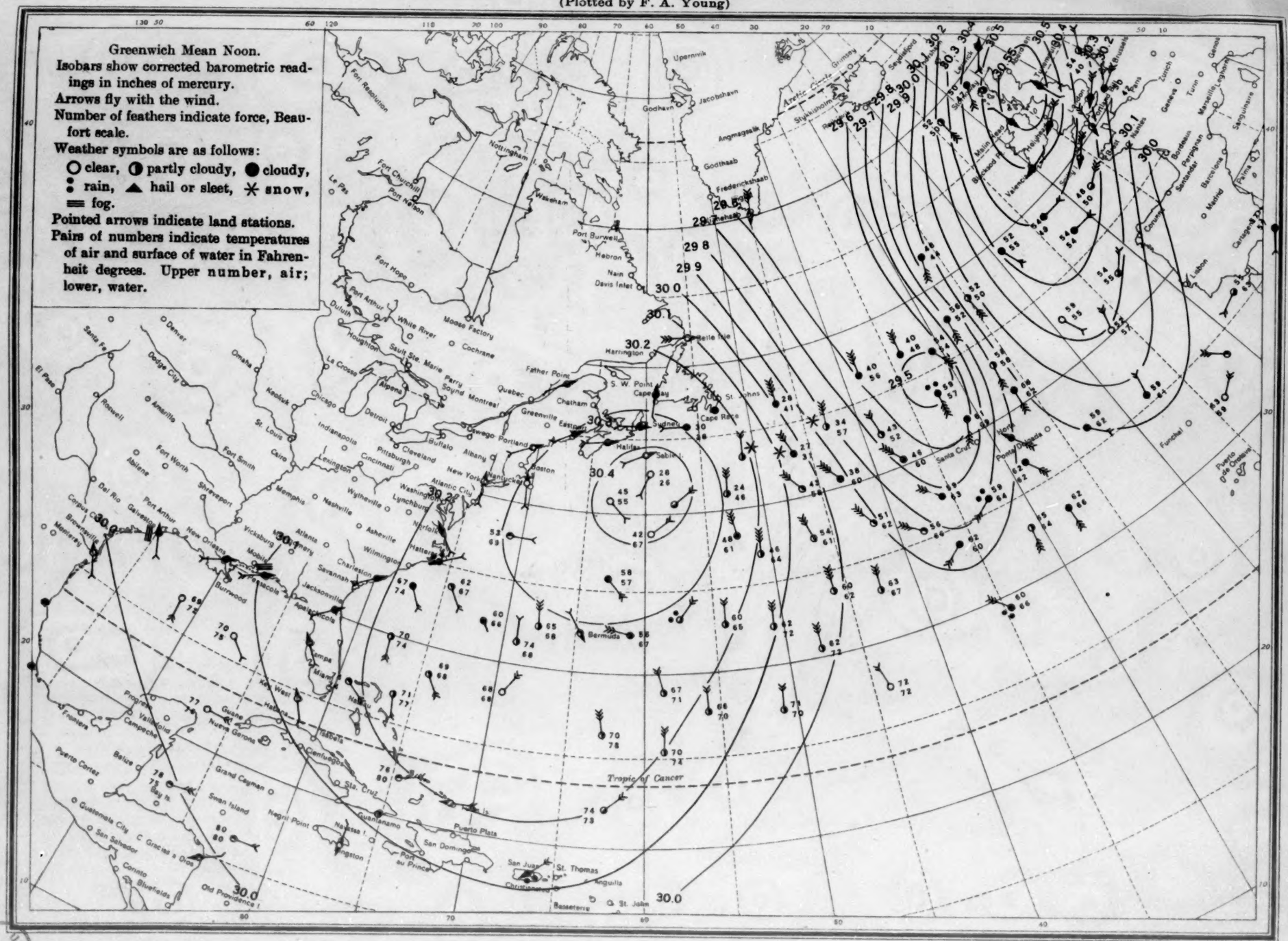

Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
clear, partly cloudy, cloudy,
rain, hail or sleet, snow,
fog.
Pointed arrows indicate land stations.
Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.
Tropic of Cancer

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Chart IX. Weather Map of North Atlantic Ocean, March 2, 1930

(Plotted by F. A. Young)

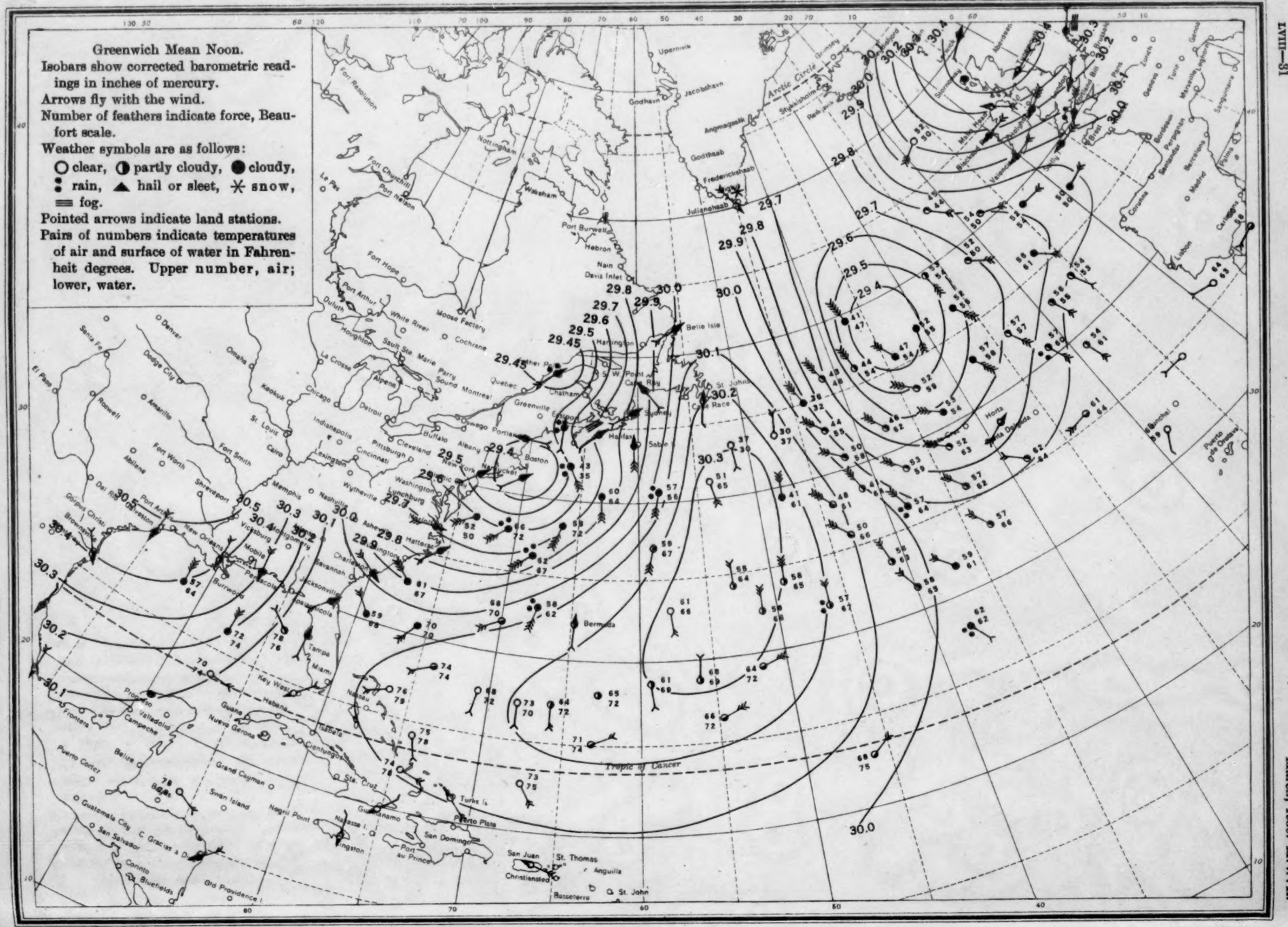

Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
clear, partly cloudy, cloudy,
rain, hail or sleet, snow,
fog.
Pointed arrows indicate land stations.
Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.
Arctic Circle
Tropic of Cancer

Chart X. Weather Map of North Atlantic Ocean, March 3, 1930

(Plotted by F. A. Young)

Chart X. Weather Map of North Atlantic Ocean, March 3, 1930

(Plotted by F. A. Young)

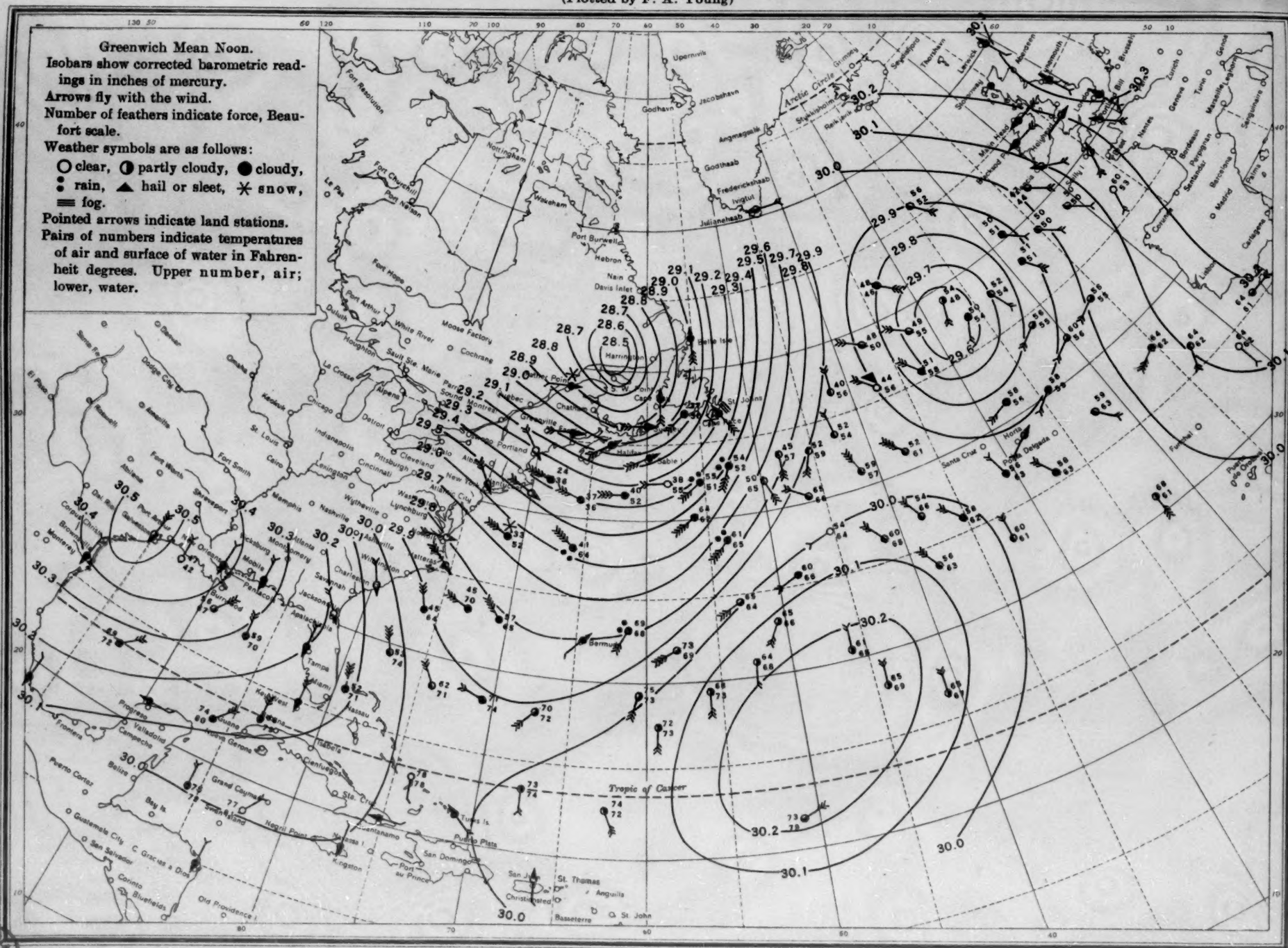
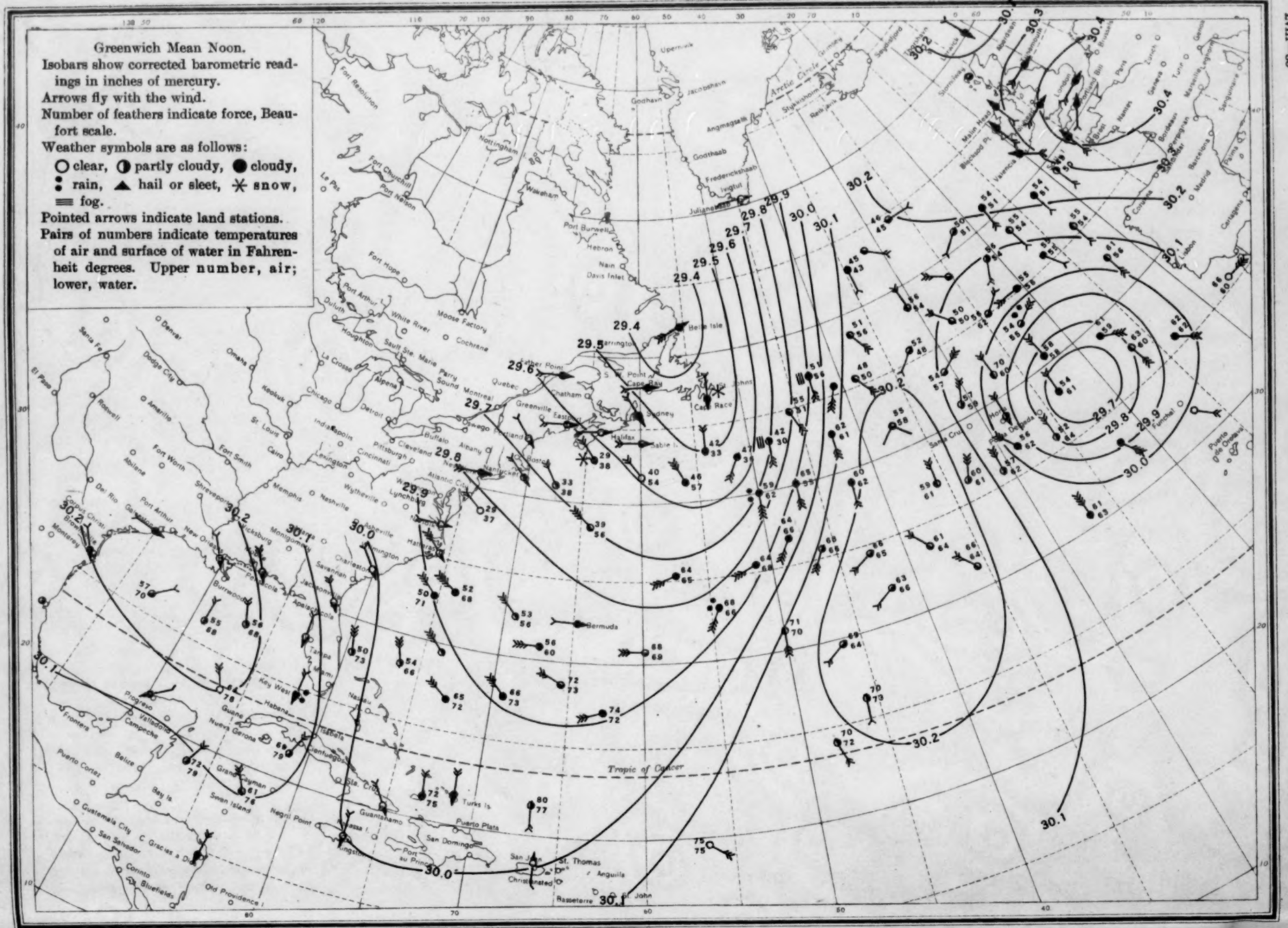

Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
clear, partly cloudy, cloudy,
rain, hail or sleet, snow,
fog.
Pointed arrows indicate land stations.
Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.
Arctic Circle
Tropic of Cancer
Godhavn
Jacobshavn
Angmagssalik
Godthaab
Fredericxhaab
Julianehaab
Upernivik
Fort Resolution
Fort Churchill
Port Nelson
Nottingham
Wakeham
Port Burwell
Hebron
Nain
Davis Inlet
Hello Isle
Harrington
Cape Race
St. Johns
Fort Hope
Port Arthur
Duluth
White River
Moose Factory
Cochrane
Houghton
Sault Ste. Marie
Quebec
Montreal
Chatham
Portland
Halifax
Sable I.
Chicago
Detroit
Buffalo
Cleveland
Pittsburgh
Cincinnati
Indianapolis
Albany
New York
Atlantic City
Lynchburg
Wytheville
Nashville
Asheville
Wilmington
Hatteras
Charleston
Savannah
Jacksonville
Tampa
Miami
Key West
Havana
Nassau
Bermuda
Turks Is.
Puerto Plata
San Domingo
Port au Prince
Kingston
Negril Point
Santiago
Guantanamo
Cienfuegos
Sta. Cruz
Grand Cayman
Belize
Puerto Cortez
Guatemala City
San Salvador
Corinto
Bluefields
C. Gracias a Dios
Old Providence I.
Progreso
Campeche
Frontera
Veracruz
Tuxpan
Tampico
Monterey
Corpus Christi
Galveston
Port Arthur
Orange
Lake Charles
New Orleans
Mobile
Pensacola
Vicksburg
Montgomery
Atlanta
Meridian
Shreveport
Memphis
Little Rock
Fort Smith
Fort Worth
Abilene
Amarillo
Dodge City
Denver
Omaha
Kansas City
St. Louis
Cairo
Louisville
Lexington
Milwaukee
La Crosse
Minneapolis
Duluth
Swift Current
Medicine Hat
Calgary
Edmonton
Prince Albert
Winnipeg
Prince Rupert
Victoria
Seattle
Portland
San Francisco
Los Angeles
San Diego
Salt Lake City
Reno
Carson City
Winnemucca
Boise
Spokane
Helena
Havre
Bismarck
Williston
Huron
Yankton
Sioux City
Des Moines
Davenport
Dubuque
Madison
Green Bay
Marquette
Sault Ste. Marie
Parry Sound
Toronto
Kingston
Ottawa
Montreal
Quebec
Chatham
Portland
Halifax
Sable I.
Hatteras
Wilmington

Chart XI. Weather Map of North Atlantic Ocean, March 4, 1930

(Plotted by F. A. Young)